PROGRAM OVERVIEW

SUNDAY, APRIL 14

15:00-18:00	**Registration** Lobby (2F)
15:00-18:00	**Welcome Drinks** Room 102 (1F)

MONDAY, APRIL 15

Room no.	205	201	202	203	204	103	104	105
08:00-08:30	**Chair Meeting** Room 206 (2F)							
08:30-09:00	**Opening** Room 205 (2F)							
09:00-10:30	**Global Review** Room 205 (2F)							
10:30-11:00	**Coffee Break** Lobby (2F)							
11:00-13:00	**Global Review** Room 205 (2F)							
13:00-14:00	**Lunch** The Party Restaurant (Exhibition Hall, B1)							
14:00-15:00	**Keynote Speech 1** Room 205 (2F)							
15:00-16:30	HSA 1	HSA 2	PSC 1	PSC 2	HSM 1	T&E 1	M&S 1	TEM 1
16:30-17:00	**Coffee Break** Lobby (2F)							
17:00-18:00	HSA 1	HSA 2	PSC 1	PSC 2	HSM 1	T&E 1	M&S 1	TEM 1
18:45-20:00	**Welcome Party** Nurimaru APEC House							

TUESDAY, APRIL 16

Room no.	205	201	202	203	204	103	104	105
08:00-08:30	**Chair Meeting** Room 206 (2F)							
08:30-09:30	**Keynote Speech 2** Room 205 (2F)							
09:30-11:00	HSA 3	HSA 4	PSC 3	PSC 4	HSM 2	T&E 2	M&S 2	HFH 1
11:00-11:30	**Coffee Break** Lobby (2F)							
11:30-13:00	HSA 3	HSA 4	PSC 3	PSC 4	HSM 2	T&E 2	M&S 2	HFH 1
13:00-14:00	**Lunch** The Party Restaurant (Exhibition Hall, B1)							
14:00-14:30	**Poster Presentation** Lobby (2F)							
14:30-15:30	**Keynote Speech 3** Room 205 (2F)							
15:30-17:00	HSA 5	HSA 6	PSC 5	PSC 6	HSM 3	T&E 3	M&S 3	GCS 1
17:00-17:30	**Coffee Break** Lobby (2F)							
17:30-18:30	HSA 5	HSA 6	PSC 5	PSC 6	HSM 3	T&E 3	M&S 3	GCS 1

WEDNESDAY, APRIL 17

Room no.	205	201	202	203	204	103	104	105
08:00-08:30	**Chair Meeting** Room 206 (2F)							
08:30-09:30	**Keynote Speech 4** Room 205 (2F)							
09:30-11:00	**HSA 7**	**HSA 8**	**PSC 7**	**PSC 8**	**HSM 4**	**PSC 9**	**M&S 4**	**TEM2**
11:00-11:30	**Coffee Break** Lobby (2F)							
11:30-12:30	**HSA 7**	**HSA 8**	**PSC 7**	**PSC 8**	**HSM 4**	**PSC 9**	**M&S 4**	**TEM2**
12:30-13:30	**Lunch** The Party Restaurant (Exhibition Hall, B1)							
13:30-14:30	**Keynote Speech 5** Room 205 (2F)							
14:30-17:00		**WS 1** High-Speed Air Intakes	**WS 2** High-Temperature Materials & Structures	**WS 3** Flight Platforms and Flight Testing	**WS 4** Detonation			
18:00-22:00	**Gala Dinner** Paradise Hotel Busan							

WS: Workshop

THURSDAY, APRIL 18

Room no.	205	201	202	203	204	103	104	105
08:00-08:30	**Chair Meeting** Room 206 (2F)							
08:30-09:30	**Keynote Speech 6** Room 205 (2F)							
09:30-11:00	**HSA 9**	**HSA 10**	**PSC 10**	**PSC 11**	**T&E 4**	**T&E 5**	**O&E 1**	**TEM 3**
11:00-11:30	**Coffee Break** Lobby (2F)							
11:30-13:00	**HSA 9**	**HSA 10**	**PSC 10**	**PSC 11**	**T&E 4**	**T&E 5**	**O&E 1**	**TEM 3**
13:00-14:00	**Lunch** The Party Restaurant (Exhibition Hall, B1)							
14:00-15:00	**Keynote Speech 7** Room 205 (2F)							
15:00-16:30	**HSA 11**	**HSA 12**	**PSC 12**	**HSM 5**	**HSM 6**	**T&E 6**	**PSC 13**	**HFH 2**
16:30-17:00	**Closing** Room 205 (2F)							

FRIDAY, APRIL 19

08:00-18:00	**Technical Tour**

HSA	High-Speed Aerodynamics and Aerothermodynamics	**TEM**	Thermal and Energy Management Systems
PSC	Propulsion Systems and Components	**GCS**	Guidance & Control Systems
HSM	High-Speed Missions and Vehicles	**HFH**	Hypersonic Fundamentals and History
T&E	Testing & Evaluation	**O&E**	Operations and Environment
M&S	Materials and Structures		


The Innovating Pioneer for a Sustainable Tomorrow
We create sustainable technologies to protect human-beings and our planet.
Hanwha Aerospace

세계를 향한 하늘길, 우주길
KAI가 만들어 갑니다
Global KAI
Beyond Aerospace
KAI는 항공기 개발의 성공 DNA가 있습니다.
KAI에는 험난한 환경에서 빛을 찾아내는 통찰력과 무모하지만
성공을 향해 달리는 도전정신, 문제를 풀어내는 창의성,
그리고 이 모든 것을 가능하게 하는 열정이 있습니다.
KAI 정신으로 하늘길, 우주길을 열겠습니다.
'글로벌 KAI 2050 비전'을 향해 달려가겠습니다.
KAI
www.koreaaero.com | TEL 055-851-1000 | FAX 055-851-1004


PLASMA
WIND TUNNEL
FOR HYPERSONIC & SPACE
RE-ENTRY SIMULATION
TEKNA
PlasmaSonic
Material testing and real time
performance measurement
under extreme conditions
Tekna.com
plasmasonic@tekna.com
Watch the video

2024 HiSST Busan

The 3rd International Conference on High-Speed Vehicle Science and Technology

CONTENTS

WECOME MESSAGES

MESSAGE FROM HISST TECHNICAL COMMITTEE

Dear Valued Conference Participants and Colleagues,

It is a pleasure and an honor to extend a warm welcome to the 3rd International Conference on High-Speed Vehicle Science and Technologies (HiSST). This conference provides a valuable platform for discussing the latest advancements in supersonic and hypersonic systems and technologies—an exciting frontier in aeronautical science. We believe that close collaboration and continuous dialogue among researchers is significantly enhancing progress in this field.

Our truly international conference brings together experts in high-speed vehicles from around the globe, facilitated by our esteemed International Technical Committee. Extensive international projects in high-speed aviation characterize the current era, and we anticipate that this conference will serve as a catalyst for uncovering new themes and possibilities for future collaborations.

We are grateful for the support of three major organizations crucial to the success of this conference. CEAS, the Council of European Aerospace Societies, is our current partner in HiSST-related activities, facilitating knowledge transfer through Technical Committees and hosting biennial European conferences. KSAS, the Korean Society for Aeronautical and Space Sciences, and KSPE, the Korean Society of Propulsion Engineers, contribute significantly to advancing aeronautical and space science and propulsion technologies as well as financial and contractual solidity to the conference execution.

As the Chair of the 3rd International Conference on High-Speed Vehicle Science and Technologies, I extend a warm welcome to the Busan Exhibition and Convention Center (Bexco), a state-of-the-art venue specialized in high-quality exhibitions and conferences.

Our objective is to enhance the global visibility of competencies, events, and publications in high-speed vehicle science and technology. We encourage scientists to publish their research outcomes in significant peer-reviewed Aeronautical and Space Journals, fostering dedicated international HiSST conferences to ensure a multi-national exchange of ideas.

The International HiSST Conference will occur every 18 months, supported by a multinational HiSST Conference Committee, in partnership with the Council of European Aerospace Societies (CEAS). Our stellar program features keynote speeches, status reports from global technical committee members, and a substantial number of technical papers. We invite your participation in social programs, award ceremonies during a gala dinner, and technical visits to points of interest.

I express our appreciation to our sponsors, Korea Tourism Organization, Busan Tourism Organization, KOFST, Pusan National University, Korea Aerospace Industries, Hanwha Aerospace, Hyundai Rotem, TENKA, Korean Air, Kimhua, Innospace, Vitzronextech, TEKNA, and the US Office of Naval Research, for their generous support.

Thank you for your dedication and participation. Without your involvement, this event would not have been possible. Once again, welcome to the 3rd HiSST Conference in Busan, Korea.

Best wishes and blue skies!

Dr. Adam SIEBENHAAR
Chair, HiSST Technical Committee

MESSAGE FROM THE LOCAL ORGANIZING COMMITTEE

Dear HiSST 2024 Participants, Colleagues, and Esteemed Guests,

It is with immense pride and profound respect for the legacy of high-speed vehicle science that I extend a warm welcome to you all to the 3rd International Conference on High-Speed Vehicle Science and Technology (HiSST 2024), set against the dynamic backdrop of Busan, South Korea. This conference marks a pivotal moment in our ongoing quest to push the boundaries of aerospace science, focusing on the thrilling domains of supersonic and hypersonic systems and technologies.

As we gather here in Busan, we stand on the cusp of a new era in aerospace engineering, driven by unprecedented progress in South Korea and collaborative ventures that span the globe. Our nation's journey in aerospace has been marked by significant milestones, from indigenously developed high-speed vehicles to pioneering ventures into space exploration. This conference is not merely a testament to these achievements but a beacon for future collaboration, innovation, and discovery.

HiSST 2024 is distinguished by its truly international spirit, bringing together the brightest minds in high-speed vehicle research from across continents. This assembly of experts, guided by an esteemed International Technical Committee, promises a fertile ground for the exchange of groundbreaking ideas and the forging of new partnerships. The path to innovation in supersonic and hypersonic technologies is complex and challenging, necessitating a synergy of expertise, resources, and vision that transcends borders.

In this spirit, the conference agenda is meticulously designed to spotlight the latest advancements, engage in depth with current challenges, and explore the infinite possibilities that lie ahead. Through a series of presentations, workshops, and discussions, we aim to catalyze the exchange of knowledge and spur on the development of technologies that will define the future of high-speed travel and aerospace defense.

As we convene in Busan, a city where tradition harmonizes with modernity, I encourage you to immerse yourselves not only in the intellectual riches of the conference but in the cultural and natural splendor of Korea. May this experience enrich your understanding, inspire your work, and invigorate your passion for aerospace science.

Looking forward, HiSST 2024 is poised to be a cornerstone event that will inspire future conferences and initiatives worldwide. It is a privilege to host this gathering in conjunction with significant milestones in Korea's aerospace journey, underscoring the deep and enduring impact of our collective endeavors.

In closing, I extend my heartfelt wishes for a productive, enlightening, and memorable conference. Together, let us embark on this exciting journey of discovery, collaboration, and innovation at HiSST 2024.

Welcome to Busan. Welcome to the future of high-speed vehicle science and technology.

Warm regards,

Prof. Dr. Jeong-Yeol CHOI
Host, Chair of Local Organizing Committee of HiSST 2024
(Pusan National University)

COMMITTEES

INTERNATIONAL TECHNICAL COMMITTEE

Australia

REPRESENTATIVE	Prof. Vincent WHEATLEY (The University of Queensland)
DEPUTY	Prof. Adrian PUDSEY (RMIT University)

Brazil

REPRESENTATIVE	Dr. Marco A.S. MINUCCI (IAS, Institute for Advanced Studies)
DEPUTY	Lucas GALEMBECK (IAS, Institute for Advanced Studies)

China

REPRESENTATIVE	Prof. Xisheng LUO (Institute of Mechanics, Chinese Academy of Sciences)
DEPUTY	Dr. Huan LIAN (Institute of Mechanics, Chinese Academy of Sciences)

Europe

REPRESENTATIVE	Prof. Johan STEELANT, Host of 2nd HiSST Conference (European Space Agency)
DEPUTY	Dr. Jeroen VAN DEN EYNDE (European Space Agency)

France

REPRESENTATIVE	Mr. Francois FALEMPIN (MBDA)
DEPUTY	Mr. Cedric MONJARET (ONERA, the French Aerospace Lab)

Germany

REPRESENTATIVE	Dr. Jan MARTINEZ-SCHRAMM (DLR, German Aerospace Center)
DEPUTY	Dr. Moritz ERTL (DLR, German Aerospace Center)

India

REPRESENTATIVE	Prof. Mohammed Ibrahim SUGARNO (Indian Institute of Technology Kanpur)

Italy

REPRESENTATIVE	Dr. Gennaro RUSSO (DAC, Campania Aerospace District)
DEPUTY	Dr. Marco MARINI (CIRA, Italian Aerospace Research Centre)

Japan

REPRESENTATIVE	Prof. Masataka MAITA (International Aerospace Consulting)
DEPUTY	Dr. Tanno HIDEYUKI (Japan Aerospace Exploration Agency)

Korea

REPRESENTATIVE	Prof. BYUN, Yunghwan (Konkuk University)
DEPUTY	Prof. CHOI, Jeong-Yeol, Host of 3rd HiSST Conference (Pusan National University)

Russia

REPRESENTATIVE	Prof. Sergey CHERNYSHEV, Host of 1st HiSST Conference (TsAGI)
DEPUTY	Dr. Nina VOEVODENKO (TsAGI)

United Kingdom

REPRESENTATIVE	Prof. Matthew MCGILVRAY (Oxford University)
DEPUTY	Dr. Luke DOHERTY (Oxford University)

United States

REPRESENTATIVE	Dr. Adam SIEBENHAAR, Committee Chairman (Mach 7H Consulting)
DEPUTY	Dr. David GLASS (NASA Langley Research Center)

HISST 2024 LOCAL ORGANIZING COMMITTEE

National Representative, TC

BYUN, Yunghwan	Konkuk University

Chair, HiSST 2024 LOC

CHOI, Jeong-Yeol	Pusan National University (PNU)

Committee Members

CHOI, Jongho	Agency for Defense Development (ADD)
DO, Hyungrok	Seoul National University (SNU)
HAN, YongMin	Korea Aerospace Research Institute (KARI)
HYUN, Seong-Yoon	Vitzronextech
JEONG, Shinkyu	Kyung Hee University
JUN, Eunji	Korea Advanced Institute of Science and Technology (KAIST)
JUNG, Suk Young	Agency for Defense Development (ADD)
KANG, Sang Hun	Konkuk University
KIM, Chun-Taek	Korea Aerospace Research Institute (KARI)
Kim, Ji Hong	Korea Aerospace Industries, Ltd., (KAI)
KIM, Kyu Hong	Seoul National University (SNU)
LEE, Bok Jik	Seoul National University (SNU)
LEE, Ho-il	Agency for Defense Development (ADD)
LEE, Hyoung Jin	Inha University
LEE, Hyung Ju	Pukyong National University (PKNU)
LEE, Joonwon	Hanwha Aerospace
LEE, Sang	Korea Advanced Institute of Science and Technology (KAIST)
LEE, Yung-Gyo	Korea Aerospace Research Institute (KARI)
NAMKOUNG, Hyuck-Joon	HYUNDAI ROTEM COMPANY
PARK, Dong-Chang	Agency for Defense Development (ADD)
PARK, Gisu	Korea Advanced Institute of Science and Technology (KAIST)
SHIN, Dong-hyuk	Korea Advanced Institute of Science and Technology (KAIST)
SHIN, Eui Sup	Jeonbuk National University
WON, Su-Hee	Korea Aerospace Research Institute (KARI)
YANG, Inyoung	Korea Aerospace Research Institute (KARI)

Advisory

BYUN, Yunghwan	Konkuk University
KIM, Chongam	Seoul National University (SNU)
SUNG, Hong-Gye	Korea Aerospace University (KAU)

CONFERENCE INFORMATION

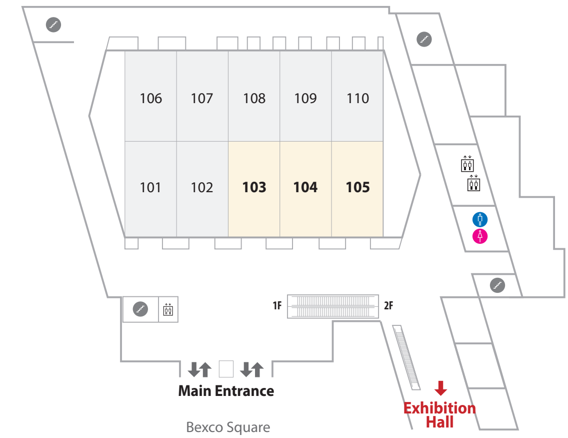
CONFERENCE VENUE

HiSST 2024 is held at the Convention Hall at BEXCO in Busan. The address is 55 APEC-ro, Haeundae-gu, Busan 48060, Republic of Korea.

FLOOR PLAN

1F, Convention Hall, BEXCO

LOCATION	PROGRAM
Rm. 102	Welcome drink (4/14 only)
Rm. 103	Oral presentation
Rm. 104	
Rm. 105	



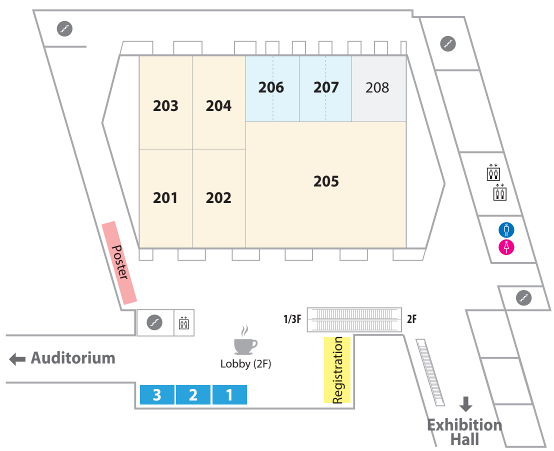
B1F, Exhibition Hall, BEXCO

LOCATION	PROGRAM
The Party	Lunch

2F, Convention Hall, BEXCO

LOCATION	PROGRAM
Lobby (2F)	Registration desk
	Exhibition & Coffee break
Rm. 201	Oral presentation
Rm. 202	
Rm. 203	
Rm. 204	
Rm. 205	Keynote speech Oral presentation
Rm. 206 L	TC room
Rm. 206 R	Gathering room
Rm. 207 L	Preview room
Rm. 207 R	Prayer room
Side lobby	Poster presentation WiPP presentation

BOOTH	COMPANY
1	Kimhua Technologies, Inc.
2	TEKNA
3	CEAS



REGISTRATION & INFORMATION DESK

The registration and information desk are located at the 2nd Floor Lobby of the Convention Hall, BEXCO.

Operating time

Sunday, April 14	15:00 – 18:00
Monday, April 15	07:30 – 18:00
Tuesday, April 16	08:00 – 18:00
Wednesday, April 17	08:00 – 18:00
Thursday, April 18	08:00 – 17:00

The registration fee includes:

Conference welcome kit
Coffee break, lunch during the conference
Welcome party
Gala dinner*
*Participation to the gala dinner is not included in the Student/Retiree registration fee. An additional ticket ($ 120) can be purchased at the registration desk (2F) on a first-come, first-served basis.

The guest category is exclusively available for partners and family members. The registration fee of the guest includes:
Welcome Party, Gala Dinner, Guest welcome kit

NAME BADGE

Name badges are expected to be worn at all times during the conference for personal identification and admission to the conference venue.

KEYNOTE SPEECHES

Keynote speeches are given at Room 205 on the second floor of Convention Hall from Monday to Thursday.

Schedule

Monday, April 15	14:00 – 15:00
Tuesday, April 16	08:30 – 09:30, 14:30 – 15:30
Wednesday, April 17	08:30 – 09:30, 13:30 – 14:30
Thursday, April 18	08:30 – 09:30, 14:00 – 15:00

TECHNICAL SESSIONS

Eight parallel sessions are held on the first and second floors of Convention Hall. The session rooms (201, 202, 203, 204, 205), preview rooms, and secretariat are on the second floors, and the session rooms (103, 104, 105) are on the first floor of Conventional Hall.

PREVIEW ROOM

All presenters are required to upload the presentation file at the preview room at least 3 hours before their presentation. Presenter will be able to upload or review/update their presentation(s) in the preview room.

LOCATION	DATE & HOURS OF OPERATION
207 (2F, Conventional Hall)	08:00-18:00, April 15 (Mon) - April 18 (Thu)

CHAIR MEETING

All session chairs for each day will conduct a meeting before the start of the morning session. During this meeting, the chairs will receive instructions for their roles as session chairs.

LOCATION	DATE & HOURS OF OPERATION
206 (2F, Conventional Hall)	08:00-08:30, April 15 (Mon) - April 18(Thu)

GATHERING ROOM

The small gathering room is available for discussions during the conference. It can accommodate up to 4 round tables with 8 people at each table. Please inquire about table reservations with the staff at the office (Room 208).

LOCATION	DATE & HOURS OF OPERATION
206 (2F, Conventional Hall)	08:30-18:00, April 15 (Mon) - April 18(Thu)

LUNCHES

Lunches are served as per the program schedule at the restaurant (The Party) on the B1 Floor of BEXCO.

COFFEE BREAKS Sponsored by KOREAN AIR

Coffee Breaks are provided as per the program schedule at the Lobby (2F), the Convention Hall.

CERTIFICATE OF ATTENDANCE

Certificate of Attendance is available for download after the conference.

SECRETARIAT OFFICE

HiSST 2024 Secretariat Office is located on the second floor. The operating time is from 8:00 to 19:00 during the conference.

LOCATION	DATE & HOURS OF OPERATION
208 (2F, Conventional Hall)	08:00-18:00 , April 15 (Mon) - April 18 (Thu)

TECHNICAL TOUR

Attendance is limited to those who have confirmed their participation in advance. Please meet at the entrance gate of Bexco Convention Hall on the 1st floor.

DATE & TIME

KAI Tour: 8:00 AM on April 19

Hanhwa Aerospace Tour: 8:40 AM on April 19

PRESENTER INSTRUCTIONS

ORAL PRESENTATION

Presentation

- The allocation time slot for your presentation is 30 minutes, including 10 minutes for Q&A.
- All presenters are requested to strictly observe their assigned presentation time.
- Presenters are asked to be in their session room at least 10 minutes before the start of the session. Report to your chair or session room staff.

Presentation file Format

- Presentations should be using Microsoft PowerPoint or Portable Document Format (PDF).
- 16:9 wide screen setting is recommended.

Audio-Visual Equipment

- The session room will be equipped with a master computer, which shall be used for all presentations.
- We do not recommend using your own laptop computer for presentation to avoid technical problems and to save time that would otherwise be needed for speaker transition.

Presentation Material Submission

- Please bring your presentation file stored on USB stick and upload it in the preview rooms at least 3 hours before your presentation. Presenter will be able to upload or review/update their presentation(s) in the preview room.
- If your presentation includes movie files and animations, please copy all the relevant files into a folder of their own creation.

POSTER PRESENTATION

Location

- Posters are presented in the Lobby (2F) of the Convention Hall.

Presentation

- Please stand in front of your poster before the poster presentation session begins.

Set-up and Remove

- Adhesive tape will be available to attach your poster to the panel.
- Mounting and removal must be done during the assigned schedule only. If not, posters will be removed by staff without notice and the organizing committee will not take responsibility for any damages or losses.

DATE	PROCESS	TIME
April 15 (Mon)	Put up posters	09:00-12:00
April 16 (Tue)	Poster presentation	14:00-14:30
April 18 (Thu)	Remove posters	17:00-

SOCIAL PROGRAM INFORMATION

WELCOME DRINK

Welcome to HiSST 2024, Venue City, Busan! We're delighted to welcome you after your long journey with a refreshing welcome drink. Pick up your registration badge and experience Korea's 'chimaek' – the perfect combination of chicken and beer.

WHEN	15:00-18:00, April 14 (Sun)
WHERE	Room 102, Convention Hall, BEXCO
INFO	Chimaek gained widespread popularity in South Korea, becoming a significant part of the country's food culture. It is often enjoyed as a casual meal or snack, commonly ordered for gatherings with friends, family, or colleagues, as well as for watching sports events or socializing at pubs and restaurants.

WELCOME PARTY

On Monday evening, all participants are kindly invited to attend the welcome party. A light welcome cocktail with finger food will be offered to all registered participants. Don't forget to bring the welcome drink coupon included in the registration name badge. The drink coupons can be exchanged for cocktails.

WHEN	18:45-20:00, April 15 (Mon)
WHERE	Nurimaru APEC House in Dongbaekseom Island Outdoor Yard(1F), Conference Rooms(2F)
ADDRESS	#119, Dongbaek-ro, Haeundae-gu, Busan, Korea

HOW TO GET TO THE VENUE

Shuttle Bus	After the session, a shuttle service will be available from BEXCO to Nurimaru. The shuttle buses will begin operating at 18:05, with seating allocated on a first-come, first-served basis. The final departure will be at 18:40.

Walk from Haeundae Beach

(from the Haeundae beach) 1.3km (15 min on foot)

If you are staying at hotels near Haeundae Beach, you can walk along the beautiful coastline to Dongbaekseom Island.
Walk to the Westin Josun Busan Hotel. Go to the main entrance of Dongbaek Island on the right side of the hotel. Or, take the left side (you will see the steps), and step onto the coastal trail (450m).

AROUND NURIMARU

Dongbaekseom Island is known for its camellia flowers in bloom during Winter and Spring. Nurimaru APEC House is probably the most significant landmark and tourist attraction at Dongbaekseom Island. It is built for the 2005 APEC Summit where the head of states from 21 Asia-Pacific countries gathered.
Views from Nurimaru APEC House is certainly a rewarding one. On the left is the island's lighthouse standing on top of the cliff. On the right is view of Gwangandaegyo Bridge and Oryukdo Islets.
On the 3rd floor main area, there is an interesting artwork on the 12 Symbols of Longevity featuring the sun, cloud, mountain, rock, water, crane, deer, turtle, pine tree, herb of eternal youth, bamboo and mythical peach.

**Nurimaru: Meaning of 'Nuri' (World) and 'Maru' (Summit).*

DONGBAEKSEOM ISLAND

Dongbaek Island (or Dongbaekseom) is located on the extreme right end of the famous Haeundae Beach in Busan. It used to be an island but is now part of the mainland by sedimentation over time. Nonetheless, it still retains its original name of an island.
At Dongbaekseom Island, there are 2 easy walking trails, a scenic coastal trail (450m) on raised wooden deck along the coastline and a circular trail (930m) around the island's nature forest. The whole walking course takes about 30-50mins.

After the walk around Dongbaekseom Island, check out The Bay 101, a waterfront yacht club with cafes, restaurants and shops. The place is particularly popular when the city lights up on nightfall or hop on a 60 mins yacht tour around Gwangan Bridge (/ Gwangandaegyo), Gwangalli Beach and Marine City.

GALA DINNER

The participants with gala dinner tickets are allowed entry to the Gala Dinner. Please bring your ticket received during registration. For student/retiree registrations, Gala Dinner ticket is not included. An additional ticket ($ 120) can be purchased at the registration desk (2F).

WHEN	18:00-22:00, April 17 (Wed)
WHERE	Grand Ballroom (2F), Paradise Hotel Busan (The cocktail reception will be held at the outdoor garden on the first floor from 6:00 PM for one hour.)
ADDRESS	#296, Haeundaehaebyeon-ro, Haeundae-gu, Busan 48099, Korea

HOW TO GET TO THE VENUE

Public Transportation

Please use public transportation to travel from BEXCO to Busan Paradise Hotel for gala dinner. Taxis or the subway are recommended for convenience.

(from the venue) **3.6 km** (13 min by car, 20 min by subway with walking)

Please take the subway from Centum City or BEXCO and get off at Haeundae Station (exit no.3). Then, head towards the beach, where you will find Paradise Hotel right in front of Haeundae Beach.

Walk from Haeundae Beach

If you are staying at hotels near Haeundae Beach, you can easily find the Paradise Hotel Busan.

(from the Haeundae beach) 0.5km (1 min on foot)

Info

The Gala dinner will include a dinner and awards ceremony that will recognize outstanding individuals who have made contributions to the field of High-Speed Vehicle Science and Technology.

The Cocktail Reception will start at 18:00 in the Sicily Room (1F) and Garden, and dinner will begin at 19:00 in the Grand Ballroom (2F). Enjoy the atmosphere of a peaceful spring night and the traditional Korean music performance

HAEUNDAE BEACH

Haeundae Beach is the most famous beach in Busan. The white sand beach is roughly 1.5 kilometers long, over a 30- to 50-meter-wide area, creating a beautiful coastline before a shallow bay, making it perfect for swimming. People flock to Haeundae Beach every summer. All kinds of accommodations from luxury hotels to private guesthouses have developed in the area around the beach, making this the perfect summer vacation spot. Haeundae Beach is also famous for various cultural events and festivals held throughout the year. Other facilities in the area include Busan Aquarium, a yachting dock, BEXCO, driving courses and more.

LOCAL INFORMATION

PUBLIC TRANSPORTATION

Metro

It is a convenient way to reach your desired destination, operating from 05:00 to 23:50. There are one-day, weekly, and monthly commutation tickets from which you can choose. The cost of the single-use ticket can vary depending on the travel distance although there is no difference in price among stations for commutation tickets. You can easily purchase a subway ticket using a ticket machine inside the station.

[Ticket vending and card reload device]

Bus

Navigating the bus system in a foreign city may seem overwhelming, but not so with Busan city buses. Each bus stop has a screen that displays the bus numbers and the minutes until the next bus arrives, and information is generally written in English and Korean.

Bus fares can be paid in cash or with a transportation card. If you use the transportation card, be sure to tap it both when you board and exit the bus. Bus stops are announced in both Korean and English, so when you hear your stop called, push the red button on the wall or handrail to ensure the bus stops for you.

- Transportation Card

Tmoney cash bee

The Korean T-Money Card is a prepaid transportation card that can be used to pay for public transportation in cities across Korea, including buses and subways. It provides cash-less travel around Korean cities, as well as offering discounts in many places. You can buy and charge a transportation card at various locations such as convenience stores, metro stations.

TAXI

Taking a taxi in Busan, Korea is very convenient, so highly recommended if you intend to explore the city on your own during the conference. Taxis can be found at taxi stands in city areas or hailed on the streets. You can either call a call taxi directly or use an app to have the taxi come to your location. Apps are usually the most convenient way to call a taxi since you can check the fare estimate in advance.

You can use Uber in Korea, although the app can either go by the name Uber or UT in Korea depending on your mobile OS. UT is a Korean navigation program that collaborated with Uber to release a Korea-exclusive call taxi app. UT is compatible with the Uber app that is already installed in a device so there's no need to change any settings if you are already an Uber user.

The base fare will vary by region, but taxis all use the same fare calculation of increase by time and distance traveled. All taxis accept credit cards, transportation cards, or cash.

The basic fare for taxis is 4, 800 KRW, and it is applied to a traveled distance within 2 kilometers, and additional charges apply for every traveled distance beyond that. A late-night surcharge of 20% applies to all taxi cabs. Late-night fare is usually applied from 22:00 to 04:00 with the surcharge varying in amount depending on the time. The late-night fare (30%) is most expensive from 23:00 to 02:00.

ATTRACTIONS IN BUSAN

Busan, a maritime city neighboring the sea, is located in the far southeast of Korea. It is the second largest city in Korea and renowned as the city of cinema, hosting Asia's largest film festival, the Busan International Film Festival (BIFF). It overflows with things to see and enjoy in every corner, such as the dazzling beach skyline, the vibrant landscape of the traditional market, the sandy beach full of people happily surfing on the waves, and the unique food alleys that represent the region. The focus of Busan travel is the sea. Centered around Haeundae Beach, one of Korea's representative resorts, cafés, and restaurants are in the Marine City area, which boasts the best skyscraper view in Korea. If you want to feel Busan, the city of movies, head to BIFF Square. Nearby are Gukje Market and Jagalchi Market. It is also fun to look around the lively market and taste street food. In addition, representative attractions include Gamcheon Culture Village, Taejongdae Park with cliffs and strangely shaped rocks, Hocheon Village with romantic night views, Korea's surfing mecca Songjeong Beach, Gwangalli Beach that has a beautiful night view of landmark Gwangandaegyo Bridge, and Dadaepo Beach famous for the enchanting golden sunset.

Haedong Yonggungsa Temple

Haedong Yonggungsa Temple is situated on the coast of the north-eastern portion of Busan. This superb attraction offers visitors the rare find of a temple along the shore line; most temples in Korea are located in the mountains. On the way to the precincts of the temple, you will first see the 12 zodiac animal deities where you can find the animal of your birth year and take pictures. The 12 gods protect the land in 12 directions, block the invasion of evil spirits, and act as fairy godmothers that wish for the five blessings. Go through the Iljumun Gate, and reach the 108 stairs connected through the pine grove to see the Haedong Yonggungsa Temple embracing the blue ocean finally. Above Yongmungyo Bridge, connected to the temple, many visitors throw coins and make wishes. Legend says that the Yonggungsa Temple grants at least one wish.

ADDRESS	86, Yonggung-gil, Gijang-gun, Busan
FROM BEXCO	20min by car (11.7 km)
ENTRANCE FEE	Free

Gamcheon Culture Village

Gamcheon has long been home to the refugees who took shelter in Busan during the Korean War. It was formerly a shantytown that was revitalized through a city regeneration project. It features colorfully painted houses clinging to the hillside and has earned the nickname "Santorini in Korea".

ADDRESS	Area of 203, Gamnae2-ro, Saha-gu, Busan
FRROM BEXCO	45min by car (22km)
ENTRANCE FEE	Free
TIP	Gamcheon Culture Village is famous for its charming scenery after sunset when the neighborhood lights up. We recommend arriving at the village no later than before sunset and admiring the nightscape after sun down.

Haeundae Blueline Park

Haeundae Blueline Park is an eco-friendly redevelopment of the former railroad facilities of the Donghae Nambu Line, a 4.8-kilometer-long stretch from Haeundae's Mipo to Cheongsapo to Songjeong. It forms a part of the new core of the Haeundae Tourism Special Zone, an international tourist region in Busan that operates the Haeundae Beach Train and Haeundae Sky Capsule along Haeundae's spectacular coastal scenery.

ADDRESS	116 Cheongsapo-ro, Haeundae-gu, Busan
FROM BEXCO	15min by car (5km, to Mipo station)
ENTRANCE FEE	Package(SKY Capsule + Beach Train) for 2 person: 59,000 (KRW) Reservation is recommended (www.bluelinepark.com)

SPA LAND Centum City

SPA LAND Centum City is the most comprehensive Korean-style spa house in the country. The massive megaplex features 22 spring-fed spas that source mineral-rich water from 1, 000 meters below ground. Add to that a sprawling open-air foot spa, plus 13 themed saunas and jjimjilbang (traditional Korean baths), and you've gotten ample opportunity to relax and rejuvenate your skin.

Standard entry passes allow 4 hours inside, although you can stretch that out to 6 if you dine at the in-house restaurant (there are enough unique experiences to pass a whole day here).

ADDRESS	35, Centum nam-daero, Haeundae-gu, Busan
FROM BEXCO	5min on foot (1F, Shinsegae Department Store Centum City)
ENTRANCE FEE	23,000 (KRW)

WHAT TO EAT IN BUSAN

Busan is well known to have delicious local and specialty food that you can only taste in Busan.

Seafood At Jagalchi Fish Market

If there is one food that defines the Busan way of life, it's seafood. Sea creatures (including sea plants) dominate menus across the port city. Seafood is often served raw – sometimes so raw it's still moving!

Jagalchi Market is one of South Korea's largest seafood market – you'll see a variety fresh and dried fish such as mackerel, ascidians, and crab displayed in wooden boxes along the road outside of the market.

The fish market at Busan is also where you can experience life in a busy seaport town – get along with the local people, get to know their culture, and try some really interesting seafood during your visit.

LOCATION	52, Jagalchihaean-ro, Jung-gu, Busan
OPEN	Daily from 5 am to 10 pm (closed every 1st and 3rd Tuesday of the month)

Milmyeon

Milmyeon consists of flour noodles in a flavorful meat-based broth, topped with cucumbers, egg, meat, and gochujang (Korea's signature chili paste which is put on everything) for spicy food lovers.

Like naengmyeon, a similar but buckwheat noodle-based dish common elsewhere in Korea, milmyeon is usually served chilled (usually with icy chunks in the broth), making it particularly refreshing in the summer. It often comes with vinegar and hot mustard on the side, and you may receive a pair of scissors to cut up the long, chewy noodles.

Ssiat Hotteok

Another defining Busan treat is ssiat hotteok, a Busan variety of hotteok, or sweet, round Korean pancakes, that are popular treats all over the country.

What sets ssiat hotteok apart is that they are stuffed with a mixture of seeds, nuts, brown sugar syrup, and cinnamon before (or sometimes after) being deep-fried to perfection. The result is drool-worthy – if you only try one sweet treat in Busan, make it this one.

TIPS!

Be prepared to line up at peak times at BIFF Square near Jagalchi Market. It's the most famous place to try ssiat hotteok.

Dwaeji Gukbap

Yet another Busan specialty is dwaeji gukbap, a meaty, body-warming, miso-based soup. The dish is time-consuming to prepare; it's made by boiling pork bones for hours, then enhanced with miso and sesame oil. Restaurants specializing in the soup are located throughout the city.

WHAT'S HAPPENING IN BUSAN

Gwangalli M Dron Light Show

The Gwangalli M Drone Light Show is held around Gwangalli Beach every Saturday as a year-round event for the first time in the nation. The Drone Light Show involves 600 unmanned aerial vehicles (drones) displaying spectacular performances that paint the night sky with various content. The show can be viewed alongside Gwangalli Beach and there are two viewing areas in front of Suyeong-gu Cultural Center and meeting square at the beach's entrance.

DATE	20:00/22:00, April 13 & April 20
FROM BEXCO	25 min by car (3km, Gwangalli Beach)
ENTRANCE FEE	Free

Broadcast live: 2024 Symphony Festival

Celebrating its 36th year, the Seoul Arts Center Symphony Festival boasts a rich history. This year, a total of 23 national and private orchestras will participate, creating an even more abundant and splendid wave of classical music. Even though we are in Busan, The Busan Cinema Center will broadcast a total of 23 performances live on a large outdoor screen at Busan Cinema Center.

ADDRESS	120, Suyeonggangbyeon-daero, Haeundae-gu, Busan
DATE	19:30 -21:00, April 3 - 28
FROM BEXCO	20 min on foot (1.4km)
ENTRANCE FEE	Free

PROGRAM

APRIL 13	APRIL 14	APRIL 16	APRIL 17	APRIL 18	APRIL 19
Daejeon Philharmonic Orchestra	Wonju City Philharmonic Orchestra	Jeju Philharmonic Orchestra	Kimcheon City Philharmonic Orchestra	Chuncheon City Philharmonic Orchestra	Seoul Metropolitan Philharmonic Orchestra

LOCAL INFORMATION

LANGUAGE

Check out the useful expression in Korean below.

Hello!	annyeonghaseyo	안녕하세요
Good-bye.	annyeonghi gaseyo	안녕히 계세요
Thank you.	gamsahamnida	감사합니다
I'm sorry.	mianhamnida	미안합니다
Excuse me.	sillyehabnida	실례합니다
It's okay.	gwaenchanhseubnida	괜찮습니다
You're welcome.	cheonman-eyo	천만에요
Good.	johseubnida	좋습니다
Would you give me a help?	dowa juseyo	도와주세요

BUSINESS HOURS

Government office hours are usually from 9:00 to 18:00 on weekdays. Banks are open from 9:00 to 16:00 on weekdays. Most stores are open every day from 10:30 to 20:00, including Sundays.

CREDIT CARDS

Visa, MasterCard, American Express, and Diners Club are widely accepted at hotels, shops and restaurants in Korea. Check with your credit card company for details using abroad.

CURRENCY & EXCHANGE

Local currency is the South Korean won (KRW, 원 in Korean, pronounced like "won"). There are four bill denominations of 1, 000, 5, 000, 10, 000, and 50, 000 "won"s. Apart from the respective denominations, notes are easily discernible by distinct colors and different portraits of historical figures on each note. As of February 14, 2024, 1 US Dollar is equivalent to about 1, 337 Korean Won (KRW) and 1 Euro is equivalent to about 1, 432 Korean Won (KRW).

Bills

Coins

TIP & TAX

Tipping is not a customary practice in Korea. Generally, 10% Value Added Tax (VAT) is levied in the total payable. Some upscale restaurants and hotel facilities may charge another 10% Service Charges. Foreigners may take a benefit of reclaiming VATs at the airport for purchases made at shops but purchased goods must be taken out of the country within three months from the purchase date to be eligible for a tax refund. Visitors can receive a refund on a receipt for a minimum purchase of KRW 30, 000.

VOLTAGE INFORMATION

The standard electricity supply is 220 volts AC/60 cycles. Most hotels may provide outlet converters for 110 and 220 volts. Participants are recommended to check with the hotel beforehand.

EMERGENCY PHONE NUMBERS

1339	Medical Emergency
119	Emergencies for Fire, Rescue & Hospital Services
112	Police
129	First Aid Services

KEYNOTE SPEAKERS

KEYNOTE SPEECH 1

14:00-15:00, April 15 (Mon)

Chiar: Prof. Vincent WHEATLEY (The University of Queensland, Australia)

Dr. Michael SMART

Hypersonix Launch Systems, Australia

BIOGRAPHY

Dr Smart is a world leader in scramjet design with particular interest in reusable space launch. He graduated with a Bachelor of Mechanical Engineering from The University of Queensland (UQ) in 1985 and completed a PhD at NYU-Poly in 1995. He then spent 10 years as a research scientist in the Hypersonic Airbreathing Propulsion Branch at NASA's Langley Research Center. He returned to Australia in 2005 and spent 15 years in the UQ Centre for Hypersonics, being appointed Professor and Chair of Hypersonic Propulsion in 2007. In December 2019 he co-founded Hypersonix Launch Systems (Hypersonix). Hypersonix is an Australian company that is developing hydrogen fuelled scramjet technology for green access-to-space.

Modern Developments in the Design of Hypersonic Inlets

Hypersonic inlet designs have developed through a range of geometric configurations, from axi-symmertric, to two-dimensional to fully three-dimensional. The key to modern designs is to take advantage of the benefits of three dimensionality in ways that satisfy broader constraints such as capability, efficiency and startability. This talk will discuss current ideas in this area.

KEYNOTE SPEECH 2

08:30-09:30, April 16 (Tue)

Chiar: Dr. David GLASS (NASA Langley Research Center, USA)

Dr. Andrew J. BRUNE

NASA Langley Research Center, USA

BIOGRAPHY

Dr. Andrew Brune has an undergraduate degree, a master's degree, and a Ph. D. degree in Aerospace Engineering from Missouri University of Science and Technology. Dr. Brune is currently a senior engineer for aerospace flight systems in the Structural and Thermal Systems Branch at the NASA Langley Research Center in Hampton, Virginia and has been working at Langley since 2012, beginning with some internships and fellowships through NASA. Since working at NASA, he has been primarily working in the area of hypersonic and entry systems, with focus on thermal protection and other high-temperature material systems. He currently serves as a technical lead and subject matter expert in planning, design, integration, hardware development, modelling, and simulation for test and evaluation of these material systems in multiple arc-jet facilities, and currently supports the Low Earth Orbit Flight Test of an Inflatable Decelerator Project and Hypersonics Technology Project. His interests also include multidisciplinary simulations, high-temperature gas dynamics, and uncertainty quantification, management, validation, and calibration related to test methods, instrumentation, and analysis approaches.

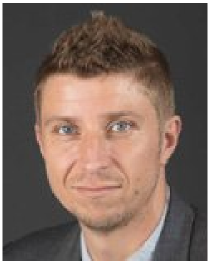
Arc-jet Overview, Modeling, and Uncertainty for Hypersonic Material Environmental Test and Evaluation

Arc-jet test facilities are crucial for testing high-temperature material systems while simulating heating and flow environments experienced in atmospheric entry and hypersonic flight. This presentation will briefly provide background on simulation parameters and the unique capability of arc-jet facilities. The primary portion of the presentation will provide a general overview of an arc jet, including components, how it works, instrumentation, and types of testing. Technical challenges and considerations will also be discussed related to arc-jet modelling and uncertainties.

KEYNOTE SPEECH 3

14:30-15:30, April 16 (Tue)

Chiar: Prof. Johan STEELANT (European Space Agency, Netherlands)



Dr. Sandy TIRTEY

Director of Rocket Lab, Australia

BIOGRAPHY

Dr. Sandy Tirtey is Rocket Lab's Director of Global Commercial Launch Services and the company's Launch Director.

Prior to Joining Rocket Lab, Dr. Tirtey did his PhD thesis in Hypersonics at the von Karman Institute (Belgium) and a Post-Doc in the group for Hypersonics at The University of Queensland (UQ) where he led the technical development of the SCRAMSPACE scramjet flight experiment from 2009 to 2013.

Dr. Tirtey joined Rocket Lab in 2013 as Vehicle Team Lead, where he supervised the development and construction of the Electron launch vehicle. In 2015, Dr. Tirtey took on the role of Vice President of Vehicle Systems, before becoming Rocket Lab's Launch Conductor in 2016. In this role, Dr. Tirtey led mission operators through the successful launches of 'It's A Test' and 'Still Testing' in 2017 and 2018, respectively.

Today, Dr. Tirtey is the Director of Global Commercial Launch Services and is based in Brisbane, Australia. In this role he supports small satellite operators globally to access orbit through frequent and reliable launch opportunities on the Electron launch vehicle. In February 2023, Dr Sandy Tirtey became Director of the newly created Rocket Lab Australia subsidiary.

Rocket Lab's HASTE vehicle - Electron for Hypersonic Flight Test

HASTE is a suborbital testbed launch vehicle derived from Rocket Lab's heritage Electron rocket. HASTE provides reliable, high-cadence flight test opportunities needed to advance hypersonic and suborbital system technology development.

KEYNOTE SPEECH 4

08:30-09:30, April 17 (Wed)

Chair: Prof. CHOI, Jeong-Yeol (Pusan National University, Korea)

Prof. Zongling JIANG

Institute of Mechanics, Chinese Academy of Sciences, China

BIOGRAPHY

Zonglin Jiang is a professor of the Institute of Mechanics, Chinese Academy of Sciences, a Distinguished Fellow of the International Shock Wave Institute. He graduated from the Department of Mechanics, Peking University and has engaged in gas dynamics research since then. Zonglin Jiang has won the AIAA 2016 Ground Test Award and authored about 300 refereed papers and published 3 academic monographs, including “Gaseous Detonation Physics and Its Universal Framework Theory” by Springer and “Theories and Technologies of Hypersonic Shock Tunnels” by Cambridge University Press.

Theories and Technologies of Detonation-driven Hypervelocity Shock Tunnels

High-enthalpy hypersonic tunnel is one of the critical technologies for hypersonics. The development of the JF-22 Hypervelocity Shock Tunnel will be reported, including the concept of the forward detonation cavity driver, the design principals of hypervelocity shock tunnels, key technologies and calibration results of the JF-22 Hypervelocity Shock Tunnel.

KEYNOTE SPEECH 5

13:30-14:30, April 17 (Wed)

Chair: Dr. Moritz ERTL (German Aerospace Center, Germany)

Prof. Hyungrok DO

Seoul National University, Korea

BIOGRAPHY

Hyungrok Do is a professor at the Department of Mechanical Engineering of Seoul National University (SNU). He earned B.S. from Mechanical and Aerospace Engineering at Seoul National University, Seoul, Korea, M.S. and Ph.D. degrees from Stanford University, CA, U.S. Prior to joining SNU, he was an assistant professor at University of Notre Dame, IN, U.S. His research interests cover hypersonic propulsion, high-pressure combustion, and laser diagnostics. He is a recipient of Air Force YIP (2015), GPPS Early Career Award (2019), and AIAA Best Paper Award (2016, 2022) for his high-speed combustion research.

Optical Diagnostics in Supersonic Combustion Environments

Quantitative measurement in supersonic combustion environments is challenging due to the limited measurement time duration in the fast-volving compressible reacting flow. To monitor and understand the flow behaviors in supersonic combustors, high-sampling rate sensors and short-exposure optical measurements are essential. Spontaneous photon emission from excited species and laser-enforced fluorescence/scattering signals can provide quantitative property information such as density, temperature, composition, and local velocity when properly processed. Some possible combinations of recently developed optical measurement methods will be presented.

KEYNOTE SPEECH 6

08:30-09:30, April 18 (Thu)

Chair: Mr. Francois FALEMPIN (MBDA, France)

Dr. Gerald HAGEMANN

ArianeGroup, Germany

BIOGRAPHY

Gerald Hagemann started his professional career 1991 with DLR Lampoldshausen, German Aerospace Center, as Ph.D. student and later on as research scientist and team leader in the field of liquid rocket propulsion.

In 1999 he joint DaimlerChrysler Aerospace (that merged later into EADS Astrium Space Transportation and then Airbus Defense and Space) as project-, programme and later on as line manager for rocket propulsion technologies. He actively participated to the creation of Airbus Safran Launchers, now ArianeGroup. Within ArianeGroup, he holds the position as “Head of Liquid Propulsion” in the Technical Directorate, and Head of Site Ottobrunn. Gerald Hagemann holds a Ph.D. from University of Stuttgart in the field of rocket propulsion.

Industry / Agency Cooperation to Face Challenges in Research

The presentation addresses research challenges for aerospace applications, and how through cooperation between industry and research partners these challenges are addressed. The discussion includes aerothermal challenges, but also material technology towards generative methods with applications where industrial standards in terms of machines are not (yet) available.

Application towards fullscale hardware and flight will be given.

KEYNOTE SPEECH 7 14:00-15:00 April 18 (Thu)

Chiar: Dr. Huan LIAN (Institute of Mechanics, Chinese Academy of Sciences)

Prof. Ming DONG

Institute of Mechanics, Chinese Academy of Sciences, China

BIOGRAPHY

Ming Dong, Professor of Institute of Mechanics, CAS. He received the PhD degree in fluid mechanics from Tianjin University, and worked there until 2021. During 2013-2014 and 2016-2018, he was working in Department of Mathematics, Imperial College London as an academic visitor and a Marie Curie Fellow, respectively. His main research interests include hydrodynamic instability, boundary-layer transition and turbulence theory. He is keen on revealing the intrinsic mechanism of flow motions by asymptotic techniques.

Impact of Surface Roughness on Hypersonic Boundary-layer Transition: from Asymptotics to Numerics

Surface roughness would influence hypersonic boundary-layer transition through the local receptivity and local scattering mechanisms, which are formulated by the high-Reynolds-number asymptotic analysis. The asymptotic theory is confirmed to be accurate by numerics, which leads to a transition-prediction model for hypersonic boundary layers with surface imperfections.

NOTE

TECHNICAL PROGRAM

ORAL PRESENTATION SCHEDULE

APRIL 14 (SUN)

15:00-18:00	**Registration** Lobby (2F), Convention Hall, BEXCO
15:00-18:00	**Welcome Drink** Room 102 (1F), Conventional Hall, BEXCO

APRIL 15 (MON)

Room No.	205
08:00-08:30	**Chair's Meeting** Room 206 (2F)
08:30-09:00	**Opening**
	Welcome Address Dr. Adam SIEBENHAAR, Chairman, HiSST Technical Committee (Mach 7H Consulting, USA)
	Host Speech Prof. Jeong-Yeol CHOI, Host of 3rd HiSST Conference (Pusan National University, Korea)
	Congratulatory Remark Dr. Chang-Jeon HWANG (President of KSAS, Korea)
	Global Review Chair: Dr. Adam SIEBENHAAR (March 7H, USA)
09:00-09:25	**Korea** Prof. Jeong-Yeol CHOI (Pusan National University)
09:25-09:50	**Australia** Prof. Vincent WHEATLEY (The University of Queensland)
09:50-10:10	**Brazil** Mr. Lucas GALEMBECK (IEAv - Institute for Advanced Studies)
10:10-10:30	**India** Prof. Mohammed Ibrahim SUGARNO (Indian Institute of Technology Kanpur)
10:30-11:00	**Coffee Break** Lobby (2F)
11:00-11:30	**China** Dr. Huan LIAN (Institute of Mechanics, Chinese Academy of Sciences)
11:30-12:00	**Europe** Prof. Johan STEELANT, Host of 2nd HiSST Conference (European Space Agency)
12:00-12:30	**US** Dr. David GLASS (NASA Langley Research Center)
12:30-13:00	**US-ONR** Dr. Eric MARINEAU (ONR's Lead Program Officer for Hypersonic)
13:00-14:00	**Lunch** The Party Restaurant (B1, Exhibition Hall)
14:00-15:00	**Keynote Speech 1** Chiar: Prof. Vincent WHEATLEY (The University of Queensland, Australia) **Modern Developments in the Design of Hypersonic Inlets** *Dr. Michael SMART (Hypersonix Launch Systems, Australia)*

Room No.	205	201	202	203	
Session	**HSA 1**	**HSA 2**	**PSC 1**	**PSC 2**	
Chairs	Dr. Moritz ERTL (DLR, Germany)	Dr. Bodo REIMANN (DLR, Germany)	Prof. Yunghwan BYUN (Konkuk university, Korea)	Dr. Tim ROOS (TNO, Netherlands)	
	Dr. Minkwan KIM (Univ. of Southampton, UK)	Prof. Rho Shin MYONG (GNU, Korea)	Prof. Antonella INGENITO (Sapienza, Italy)	Prof. Kun WU (IMCAS, China)	
15:00-15:30	**HiSST 2024 - 202** **Surface Catalytic Effect on Chemical Heat Flux using Direct Simulation Monte Carlo** *Youngil KO, Eunji JUN (KAIST, Korea)*	**HiSST 2024 - 047** **An Investigation of Internal Drag Correction Methodology for Wind Tunnel Test Data in a High-Speed Air-Breathing Vehicle using Numerical Analysis** *Younghwan LEE (ADD/SNU, Korea), Hyeon JIN, Min-Gyu KIM (ADD, Korea), Hyungrok DO (SNU, Korea)*	**HiSST 2024 - 025** **A Numerical Study of Supersonic Intakes** *Jimmy-John HOSTE, Bruno PIAZZA, Fernando MIRO-MIRO (Destinus, Switzerland)*	**HiSST 2024 - 109** **Feasibility Study of an Electric Supersonic Propeller** *Jens KUNZE, Allan PAULL (UQ, Australia)*	**Exper Assess** *Giov Bas Lu*

2024 HiSST Busan

The 3rd International Conference on
High-Speed Vehicle Science and Technology

204	103	104	105
HSM 1	**T&E 1**	**M&S 1**	**TEM 1**
Mr. Lucas GALEMBECK (IAS, Brazil)	Prof. Hyungrok DO (SNU, Korea)	Dr. Roberto GARDI (CIRA, Italy)	Mr. Francois FALEMPIN (MBDA, France)
Dr. Martin SIPPEL (DLR-SART, Germany)	Dr. Dermeval CARINHANA JR (IAS, Brazil)	Mr. Ron SHARABANI (IAI, Israel)	Prof. Hyung Ju LEE (PKNU, Korea)
HiSST 2024 - 027	**HiSST 2024 - 367**	**HiSST 2024 - 026**	**HiSST 2024 - 192**
rimental Outdoor Activity on Sonic Boom sment of the STRATOFLY MR3 Scale Model	**Flight Qualification of the Red Kite Solid Rocket Motor**	**Development of a Dual-Layer Ablator for Spacecraft Heat Shield Applications**	**Performance of a Transpiration-Cooled Sharp Leading Edge for Hypersonic Flight**
vanni FASULO (CIRA, Italy), Sébastien HENGY, tien MARTINEZ (ISL, France), Luigi FEDERICO, ciano DE VIVO (CIRA, Italy), Marie ALBISSER, Andreas ZEINER (ISL, France)	*Thomas RÖHR, Frank SCHEUERPFLUG, Josef ET TL, Dietmar KAIL, Christian MILDENBERGER, Johannes RIEHMER, Christian SCHNEPF, Rainer KIRCHHARTZ (DLR, Germany)*	*Rajesh Kumar CHINNARAJ, Young Chan KIM, Seong Man CHOI (JBNU, Korea)*	*Raghul RAVICHANDRAN, Luke DOHERTY, Matthew MCGILVRAY (Univ. of Oxford, UK)*

APRIL 15 (MON)

Room No.	205	201	202	203
Session	**HSA 1**	**HSA 2**	**PSC 1**	**PSC 2**
15:30-16:00	**HiSST 2024 - 051** Radiation Computations and Ionisation Effects for Hypersonic Flow in Thermo-Chemical Nonequilibrium *Dominik JAMES, Christian MUNDT (UniBw M, Germany)*	**HiSST 2024 - 079** Vibrational Non-equilibrium Effects in Compressed and Expanding Hypersonic High Enthalpy Flow *Jan MARTINEZ SCHRAMM, Georgii OBLAPENKO (DLR, Germany)*	**HiSST 2024 - 041** Verification of Variable Inlet Design through Wind Tunnel Test *Young Jin KIM, Hyoung Jin LEE (Inha Univ., Korea)*	**HiSST 2024 - 131** Off-Design and Transient Simulation of an Expander-Type Air-Turbo-Rocket *Karel VAN DEN BORRE, F. PETTINATO, Bayindir Huseyin SARACOGLU (VKI, Belgium)*
16:00-16:30	**HiSST 2024 - 126** Internal Flow Path Analysis of the Scramjet Hypersonic Experimental Vehicle *Oreste RUSSO, Pietro RONCIONI, Marco MARINI, Sara DI BENEDETTO (CIRA, Italy), Giuliano RANUZZI, Simone PIZZURRO (ASI, Italy)*	**HiSST 2024 - 227** Numerical Study on Heat Fluxes in Hypersonic Flow over a 3D Sharp Cone *Soham SINHA, MOHAMMED IBRAHIM SUGARNO (IIT Kanpur, India)*	**HiSST 2024 - 095** Preliminary Study of High-speed Variable Geometry Two-dimensional Inlet Design *Jun LIU, Xueju QIU, Huacheng YUAN (NUAA, China)*	**HiSST 2024 - 157** Conceptual Design of Hypersonic Combined Cycle Engines *Hideyuki TAGUCHI, Hidemi TAKAHASHI, Shunsuke IMAMURA, Sadatake TOMIOKA (JAXA, Japan)*
16:30-17:00	**Coffee Break** Lobby (2F)			
17:00-17:30	**HiSST 2024 - 111** Assessment of Uranus Planetary Entry Conditions in the X2 Expansion Tube for Performing Infrared Thermography *Matthew UREN, Yu LIU, Chris JAMES, Richard MORGAN (UQ, Australia)*	**HiSST 2024 - 054** Analysis of the Cooling Performance of the Scramjet Regenerative Cooling Channel according to the Aspect Ratio using the Conjugate Heat Transfer Analysis *Jae Seung KIM, Song Hyun SEO, Kyu Hong KIM (SNU, Korea)*	**HiSST 2024 - 242** Experimental Performance Evaluation of a Streamline Traced Inlet at Off-Design Conditions *Andrew PILKINGTON, Luke J DOHERTY, Chris J HAMBIDGE, Matthew MCGILVRAY (Univ. of Oxford, UK), Tristan VANYAI, Vincent WHEATLEY (UQ, Australia)*	**HiSST 2024 - 193** Properties of Direct Current Discharge in a Supersonic Flow, and Its Application for Plasma-Assisted Combustion *Aleksandr A. FIRSOV, Anastasia S. DOBROVOLSKAYA, Dmitriy A. TARASOV, Roman S. TROSHKIN, Valentin A. BITYURIN, Aleksey N. BOCHAROV (JIHT RAS, Russian Federation)*
17:30-18:00	**HiSST 2024 - 125** Heat Flux Augmentation Caused by Surface Imperfections in Turbulent Boundary Layers *William IVISON, Chris J HAMBIDGE, Matthew MCGILVRAY (Univ. of Oxford, UK), Alan FLINTON, Jim MERRIFIELD (FGE Ltd, UK), Johan STEELANT (ESA-ESTEC, Netherlands)*	**HiSST 2024 - 053** Fluid-thermal-structural coupled study on rudder leading edge with porous opposing jet in hypersonic flows *Shaliang LI, Bing LIU, Shibin LI, Wei HUANG, Lin WANG (NUDT, China)*	**HiSST 2024 - 328** Numerical Study of Turbulent Combustion in High Mach Number Scramjet Engine with Thermodynamic Non-equilibrium Effect *Hai FENG, Tai JIN (ZJU, China), Kun WU ((IMCAS), China)*	
18:45-20:00	**Welcome Party** Nurimaru APEC House			

APRIL 15 (MON)

204	103	104	105
HSM 1	**T&E 1**	**M&S 1**	**TEM 1**
HiSST 2024 - 191 The SCX-01 Atmospheric Re- entry Demonstrator and Thermostructural Ablative TPS Flight Experiment *G. PINAUD, J. BERTRAND, T. Pichon, S. Pams, G. Foulon (ArianeGroup, France)*	**HiSST 2024 - 289** Free-flying Model Testing in the X2 Expansion Tube *Christopher M. James, James J. Wallington, Thien Bui, Daisy-May Joslyn, Elsie Edwards, Raeph Mason, Jack McKay, Rose Butler, Flynn Pearman, Torri Young (UQ, Australia)*	**HiSST 2024 - 317** Exploratory Design and Evaluation of Alumina-Based Oxide/Oxide Ceramic Matrix Composite for Integrated Thermal Protection System Application *Vinh Tung LE, Abhendra K SINGH (Baylor Univ., USA)*	**HiSST 2024 - 178** Experimental Study on Thermal Decomposition Characteristics of exo-THDCPD *Seung Mook PARK, Hyung Ju LEE, Seung Mook PARK, Seung Hyeon LEE (PKNU, Korea)*
HiSST 2024 - 213 The Scramjet Hypersonic Experimental Vehicle *Sara DI BENEDETTO, Marco MARINI, Pietro RONCIONI, Antonio VITALE, Paolo VERNILLO, G. DI LORENZO, Roberto SCIGLIANO (CIRA, Italy), Salvatore CARDONE (Tecnosistem, Italy), Marta ALBANO, Roberto BERTACIN (ASI, Italy)*	**HiSST 2024 - 365** Design and Objectives of the Air-breathing Propulsion Experiment Technology Demonstrator (APEX-TD) *Johannes RIEHMER, Florian KLINGENBERG, Thomas RÖHR, Christian ZUBER, Christian SCHNEPF, Ali GÜLHAN (DLR, Germany)*	**HiSST 2024 - 134** Preliminary Thermal Assessment of an Air-launched Propelled Hypersonic Experimental Vehicle *Roberto SCIGLIANO, Marco MARINI, Sara DI BENEDETTO (CIRA, Italy), Marta ALBANO, Giuliano RANUZZI (ASI, Italy)*	**HiSST 2024 - 212** Transpiration Cooled Fin Flight Experiment FinEx II on HIFLIER1 *Giuseppe D. DI MARTINO, Jonas PEICHL (DLR, Germany), Fabian HUFGARD, Christian DÜRNHOFER, Stefan LÖHLE (HEFDiG, Germany), Johannes GÖSER (DLR, Germany)*
Coffee Break Lobby (2F)			
HiSST 2024 - 267 Overview of the DRACO Development Status *Jeroen VAN DEN EYNDE, Beatriz JILETE, Alex ROSENBAUM, Stijn LEMMENS (ESTEC, Netherlands)*	**HiSST 2024 - 326** The Current Status of Free-Flight Testing of a Scramjet-Integrated Hypersonic Cruising Vehicle Model in the HIEST Free-Piston Shock Tunnel *Hideyuki TANNO, Shuto YATSUYANAGI, Kouichiro TANI, Sadatake TOMIOKA (JAXA, Japan)*	**HiSST 2024 - 229** Optimization and Characterization of CARBOTEX®-Si, a CMC for Hypersonic Applications *Félix BAN, Tobias SCHNEIDER, François FALEMPIN, Stephan SCHMIDT-WIMMER (MBDA, France)*	**HiSST 2024 - 217** Inflatable Heat Shields Solutions for Hypersonic Re-entry Applications: the European Commission EFESTO-2 Project *Giuseppe GUIDOT TI, Federico TOSO, Alessandro PRINCI, Jaime GUTIERREZ BRICEÑO (Deimos Space S.L.U, Italy), Giuseppe GOVERNALE, Nicole VIOLA (Politecnico di Torino, Italy), Ingrid DIETLEIN, S. Callsen, K. Bergmann, Junnai ZHAI, Thomas GAWEHN (DLR, Germany), Roberto GARDI, Barbara TISEO (CIRA, Italy), Ysolde PREVEREAUD, Yann DAUVOIS, C. Julien (ONERA, France), Giovanni GAMBACCIANI, Giada DAMMACCO (PGZ, Italy), L.Garcia-Basabe (Deimos Engenharia, Portugal)*
HiSST 2024 - 273 Preliminary Conceptual Design of the Reusable Unmanned Space Vehicles using Multidisciplinary Optimization *Dabeen JEONG, Shinkyu JEONG (KHU, Korea), Jongho JUNG (SNU, Korea)*	**HiSST 2024 - 354** Active and Passive Vibration Control Technology for Trisonic Wind Tunnel Models *Huanhuan YAN, Wenbin NI, Junfei WU, Xiaojun PAN, Jian ZHOU, Wanfang YAN, Sen LIU, Tiejin WANG, Jiang ZHANG (CAAA, China)*	**HiSST 2024 - 215** Deformation Measurement of Stainless Steel in High-temperature Environments using DIC for Thermal Protection System *Nam Seo GOO, Xiongjie CHE (Konkuk Univ., Korea)*	
Welcome Party Nurimaru APEC House			

APRIL 16 (TUE)

Room No.	205	201	202	203
08:00-08:30	**Chair's Meeting** Room 206 (2F)			
08:30-09:30	**Keynote Speech 2** Chiar: Dr. David GLASS (NASA Langley Research Center, USA) **Arc-jet Overview, Modeling, and Uncertainty for Hypersonic Material Environmental Test and Evaluation** *Dr. Andrew J. BRUNE (NASA Langley Research Center, USA)*			
Session	**HSA 3**	**HAS 4**	**PSC 3**	**PSC 4**
Chairs	Prof. Eunji JUN (KAIST, Korea)	Prof. Rho Shin MYONG (GNU, Korea)	Dr. Inyoung YANG (KARI, Korea)	Prof. Bok Jik LEE (SNU, Korea)
	Prof. Alexandre MARTIN (Univ. of Kentucky, USA)	Prof. Christian MUNDT (UniBw M, Germany)	Dr. Jun LIU (NUAA, China)	Prof. Antonella INGENITO (Sapienza, Italy)
09:30-10:00	**HiSST 2024 - 137** HIFiRE-5 Testing in the Oxford High Density Tunnel *Samuel BROADHURST, Luke DOHERTY, Matthew MCGILVRAY, William IVISON, Chris HAMBIDGE (Univ. of Oxford, UK)*	**HiSST 2024 - 188** A Study on the Aerodynamics and Aerothermodynamics of a Supersonic Reefed Parachute *Weijie XU, Yi LI (NWPU, China)*	**HiSST 2024 - 315** Design and Starting Study of the Adjustable Inward Turning Inlet at Ma1.5~7 *Fuzhou LIU, Huacheng YUAN, Keyu ZHOU, Zhenggui ZHOU (NUAA, China)*	**HiSST 2024 - 076** Knowledge Discovery on Cavity-Based Scramjet Combustor Design via Stochastic-Surrogate-Assisted Multi-Objective Optimization *Chihiro FUJIO (Kyushu Univ., Japan), Sasi Kiran PALATEERDHAM, Lakshmi Narayana Phaneendra PERI (Sapienza, Italy), Hideaki OGAWA (Kyushu Univ., Japan), Antonella INGENITO (Sapienza, Italy)*
10:00-10:30	**HiSST 2024 - 179** Investigation on the Linear Stationary Crossflow Stability Characteristics of Hypersonic Boundary Layer with Expansion Corner *Peisen LU, Youcheng XI, Song FU (Tsinghua Univ., China)*	**HiSST 2024 - 240** Numerical Investigation of Magnetic Heat Flux and Electron Manipulation System for Hypersonic Vehicles *Thomas J. GREENSLADE, Arunkumar CHINNAPPAN, Minkwan KIM (UoS, UK)*	**HiSST 2024 - 034** Design of a Truncated Ideal Nozzle for a Re-usable First Stage Launcher *Sebastian KARL, Tamas BYKERK, Mariasole LAURETI (DLR, Germany)*	**HiSST 2024 - 081** Numerical Study of Vitiation Air Effects on the Hydrogen-fueled Direct-Connect Scramjet Combustor *Seung-Min JEONG, Jae-Eun KIM, Mun-Soo KIM, Jeong-Yeol CHOI (PNU, Korea)*
10:30-11:00	**HiSST 2024 - 197** Frequency Modulation Analysis in Innovate Supersonic Cavity Flow *Ting Tsung CHANG, Konstantinos KONTIS (Univ. of Glasgow, UK)*	**HiSST 2024 - 129** Experimental Visualization of Hypersonic Boundary Layer Transition *Duk-Min KIM, Hyoung Jin LEE (Inha Univ., Korea)*	**HiSST 2024 - 110** High Fidelity Simulation of Liquid Jet Breakup in Supersonic Crossflow *DongGyu YUN, Hong-Gye SUNG (KAU, Korea)*	**HiSST 2024 - 130** Thermally Choked Nozzle 1D Model for Low-Mach Dual Mode Scramjet Performance Assessment *Jean-Etienne DURAND, Frédéric OLIVON (ONERA, France)*
11:00-11:30	**Coffee Break** Lobby (2F)			

APRIL 16 (TUE)

204	103	104	105
Chair's Meeting Room 206 (2F)			

HSM 2	T&E 2	M&S 2	HFH 1
Dr. Michael SMART (Hypersonix Launch Systems Ltd, Australia)	Dr. Jan MARTINEZ SCHRAMM (DLR, Germany)	Prof. Ikhyun KIM (Keimyung Univ., Korea)	Prof. Ming DONG (IMCAS, China)
Dipl. Dr. ing. Marius FRANZE (DLR, Germany)	Dr. Ajmal MOHAMED (ONERA, France)	Dr. Jonathan RAYNAUD (MBDA, France)	Prof. Caihong Su (Tianjin University, China)
HiSST 2024 - 220 Experimental Aeroshape Characterization of an Inflatable Heat Shield Re-entry Vehicle in the EFESTO-2 Project *Junnai ZHAI, Thomas GAWEHN, Ali GÜLHAN (DLR, Germany), Ysolde PREVEREAUD, Yann DAUVOIS (ONERA, France), Giuseppe GUIDOTTI (Deimos Space S.L.U., Spain), Giuseppe GOVERNALE (Politecnico di Torino, Italy)*	**HiSST 2024 - 277** Temperature Sensitive Paint Techniques for Ultra High Speed Acquisition their Development towards the Determination of Flight Temperatures *Jan MARTINEZ SCHRAMM, Divek SURUJHLAL, Leni SCHMIDT (DLR, Germany)*	**HiSST 2024 - 340** Design and Post-Test Analysis of PWT Testing on CMC and UHTCMC Materials *Giuseppe Maria INFANTE, Leonardo Luca MELLONE, Daniele GUIDA, Carlo PURPURA, Mario DE STEFANO FUMO (CIRA, Italy), Alessandro AIROLDI, Antonio Maria CAPORALE, Marco RIVA (Politecnico di Milano, Italy)*	**HiSST 2024 - 275** SWBLI Effects of Impinging Shock on a Flat Plate in High Mach Number Flows *Aishwarya PS, Mohammed Ibrahim SUGARNO (IIT Kanpur, India)*
HiSST 2024 - 071 Progress Pre-definition of the SpaceLiner 8 Advanced Hypersonic Transport *Martin SIPPEL, Jascha WILKEN, Leonid BUSSLER, Steffen CALLSEN, Tommaso MAURIELLO (DLR-SART, Germany)*	**HiSST 2024 - 123** Initial Investigation of a Combustion-Driven Shock Tunnel Operating as a Shock Tube *Marco A. S. MINUCCI, Israel S. RÊGO, Marcos M. BORGES, Giannino P. CAMILLO, Lucas A. G. RIBEIRO, Rafael O. SANTOS, Thiago L. ASSUNÇÃO, Ivo P. M. ALVES, Thiago V. C. MARCOS, Bruno B. NASCIMENTO, Pedro S. MATOS, Lucas GALEMBECK, Dermeval CARINHANA JR (IAS, Brazil)*	**HiSST 2024 - 039** Temperature Effect on Erosion by Atomic Oxygen in LEO Environment Using Reax-FF Molecular dynamics *Jiwon JUNG, Jongkyung AN, Seunghwan KWON, Gun Jin YUN (SNU, Korea)*	**HiSST 2024 - 280** Some Recent Developments in Hypersonic Flow Stability Analyses *Liang WANG, Song FU (Tsinghua Univ., China)*
HiSST 2024 - 219 Numerical Aeroshape Characterization of an Inflatable Heat Shield Re-entry Vehicle in the EFESTO-2 Project *Ysolde PREVEREAUD, Yann DAUVOIS (ONERA, France), Junnai ZHAI, Thomas GAWEHN (DLR, Germany), Giuseppe GUIDOTTI (Deimos Space S.L.U, Spain), Giuseppe GOVERNALE (Politecnico di Torino, Italy)*	**HiSST 2024 - 195** Tailored Operating Conditions in the T6 Reflected Shock Tunnel *Joshua ASHBY, Matthew MCGILVRAY (Univ. of Oxford, UK)*	**HiSST 2024 - 319** Acoustic Shock Wave-induced Phase Transition of Indium Selenide from Orthorhombic to Rhombohedral Crystal System *S. A Martin BRITTO DHAS, S. OVIYA, F. Irine Maria BINCY (AKRC, India), Ikhyun KIM (Keimyung Univ., Korea)*	**HiSST 2024 - 175** Heat Flux Increment Induced by the Coupled Shear and Compression Effects in Laminar Hypersonic Flows *Huijun GAO, Zhi hui WANG (UCAS, China)*

Coffee Break Lobby (2F)

APRIL 16 (TUE)

Room No.	205	201	202	203
Session	**HSA 3**	**HAS 4**	**PSC 3**	**PSC 4**
11:30-12:00	**HiSST 2024 - 249** Aerodynamics of the Reusable Launch Vehicle Supersonic Retropropulsion System *Jesslyn Wei Yan ONG, Yujoo KANG, Jaemyung AHN, Sang LEE (KAIST, Korea)*	**HiSST 2024 - 127** Aerodynamic and Propulsive Assessment of an Experimental Hypersonic Scramjet System *Pietro RONCIONI, Oreste RUSSO, Francesco CASCONE, Marco MARINI, Sara Di BENEDETTO (CIRA, Italy), Marta ALBANO, Roberto BERTACIN (ASI, Italy)*	**HiSST 2024 - 333** IDDES Modeling of a Dual-Mode Scramjet by Dynamic Zone Flamelet Model with Sensitivity Analysis of Zoning Parameter *Zheng ZHANG, Wei YAO (IMCAS, China*	**HiSST 2024 - 368** The Red Kite Sounding Rocket Motor Qualification Milestones and Application Spectrum *F. SCHEUERPFLUG, T. RÖHR, T. HUBER, M. REINOLD, D. HARGARTEN, L. KOBOW, R. KIRCHHARTZ (DLR, Germany), M. KUHN, A. WEIGAND, M. BERNDI, J. WERNETH (Bayern-Chemie GmbH, Germany)*
12:00-12:30	**HiSST 2024 - 226** Design of Pulsed Magnetic Circuit with Pulse Forming Network for Experimental Study of Magnetohydrodynamic Aerobraking *Takeaki MURAMATSU, Yosuke KUROSAKA, Kohei SHIMAMURA, Akira KAKAMI (TMU, Japan), Hiroshi KATSURAYAMA (Tottori Univ., Japan)*	**HiSST 2024 - 230** Investigation of Aerodynamic Coefficient and Compressibility Effect of AGARD-B Model Based On Wind Tunnel Experiment and CFD Simulation *Hung-Yen CHOU, Hsien-Hao TENG (NCSIST, R.O.C.)*	**HiSST 2024 - 058** LES Investigation of Thermally Choked Mode Combustion Characteristic of the Dual Combustion Ramjet Engine *Min-Seon JO, Bu-Kyeong SUNG CHOI (PNU, Korea), Seung-Min JEONG (KARI, Korea), Jeong-Yeol CHOI (PNU, Korea)*	**HiSST 2024 - 037** Experimental and Numerical Research on a Design Concept of Two-stage Compression Inward-turning TBCC Inlet *Zhancang HU, Yiqi TANG (Xiamen Univ., China), Zhonglong LI (AECC Sichuan Gas Turbine Establishment, China), Zejun CAI, Zhenqi SUN, Chengxiang ZHU, Yancheng YOU (Xiamen Univ., China)*
12:30-13:00	**HiSST 2024 - 265** Hypersonic Crossflow-induced Breakdown and Transition Correlation Based on Secondary instability Modes on a Swept Flat Plate *Gen LI, Caihong SU (Tianjin Univ., China)*	**HiSST 2024 - 106** A 3D Parallel Lagrangian Finite Volume Scheme for Ideal MHD Equations *Xiao XU, Hongbo LU, Jian LIN, Feng JI, Nong CHEN (CAAA, China)*	**HiSST 2024 - 120** Numerical Study on Post-Combustion Chamber Impact on Hybrid Rocket Performance *Andrija DABANOVIC, Joël MARTIN, Stefan MAY, Viola WARTEMANN (DLR, Germany)*	**HiSST 2024 - 180** Observation of Hydrogen Combustion Characteristics in a Scramjet Combustor Based on Cavity Type *Geon Wook YIM, Hyoung Jin LEE (Inha Univ., Korea)*
13:00-14:00	**Lunch** The Party Restaurant (B1, Exhibition Hall)			
14:00-14:30	**Poster Presentation** Side Lobby (2F)			
14:30-15:30	**Keynote Speech 3** Chair: Prof. Johan STEELANT (ESA ESTEC, Netherlands) **Rocket Lab's HASTE vehicle – Electron for Hypersonic Flight Test** ***Dr. Sandy TIRTEY (Director of Rocket Lab Australia, Australia)***			
Session	**HSA 5**	**HSA 6**	**PSC 5**	**PSC 6**
Chairs	Prof. Sang LEE (KAIST, Korea)	Prof. Chongam KIM (SNU, Korea)	Prof. Hyunchang LEE (Kyungnam Univ., Korea)	Dr. Dermeval CARINHANA JR (IAS, Brazil)
	Dr. Jimmy-John HOSTE (Destinus, Switzerland)	Dr. Tamara SOPEK (UniSQ, Australia)	Dr. Marc FERRIER (ONERA, France)	Dr. Tristan VANYAI (UQ, Australia)
15:30-16:00	**HiSST 2024 - 029** A Boundary Layer Analysis on the HEXAFLY-INT Experimental Flight Test Vehicle *Frederik JACOBS, Johan STEELANT (ESTEC, Netherlands)*	**HiSST 2024 - 256** Hypersonic Flow over the Double Wedge in Low and High Enthalpy Free Stream Conditions *Anurag RAY, Ashoke DE (IIT Kanpur, India)*	**HiSST 2024 - 093** Design and Commissioning of TNO's modular Rotating Detonation Engine (RDE) test facility *Tim ROOS, Wolter WIELING (TNO, Netherlands), Moana LENGKEEK (TU Delft, Netherlands), Martin OLDE (TNO, Netherlands)*	**HiSST 2024 - 082** Numerical Study on Unstart Characteristics of Scramjet Engine Induced by Fuel Injection *Hyunwoo KIM, Hong-Gye SUNG (KAU, Korea)*

APRIL 16 (TUE)

204	103	104	105
HSM 2	**T&E 2**	**M&S 2**	**HFH 1**
HiSST 2024 - 353 Establishment of System Engineering Procedure for Two-Stage Sounding Rocket *Si-Yoon KANG, Min-Seon JO, Joungsu OH, Inhoi KOO, Keon-Hyeong LEE, Jeong-Yeol CHOI (PNU, Korea)*	**HiSST 2024 - 384** Development of an Approach that Delivers a High-Tempo of High Speed Flight Trials at Affordable Costs *Allan PAULL, Jens KUNZE, Sampada SHELAR, Nathan PAULL, Tom WATTS (UQ, Australia)*	**HiSST 2024 - 342** Development of a Numerical Tool for Step & Gap Prediction on Space Rider Windward *Leonardo Luca MELLONE, Giuseppe Maria INFANTE, Mario De Stefano FUMO, Giuseppe Carmine RUFOLO (CIRA, Italy)*	**HiSST 2024 - 204** Interaction of Mainstream Injection with Boundary Layer Combustion for Hydrogen Fuel *Jacob SANDRAL, Tristan VANYAI, Anand VEERARAGAVAN, Vincent WHEATLEY (UQ, Australia)*
HiSST 2024 - 100 First Hot Combustion Subsonic Retro Propulsion Tests in the Vertical Free Jet Facility Cologne (VMK) *Ansgar MARWEGE, Daniel KIRCHHECK, Ali GÜLHAN (DLR, Germany)*	**HiSST 2024 - 182** Drag due to Distributed Roughness in Supersonic Turbulent Boundary Layers: Comparison between Experiments and Numerics *Quentin CHANZY, Antoine DURANT (MBDA, France), Sylvain MORHILAT, Vincent BRION (ONERA, France)*	**HiSST 2024 - 183** A Study on the Mechanical Properties and Microwave Absorption Performance of Nickel-coated Basalt Fiber/aluminosilicate Ceramic Composite Applicable to Hypersonic Vehicle *Kwonwoo PARK, Hoyoung SHIN (GNU, Korea), Dongjun HONG (KAU, Korea), Hyunseok KO (KICET, Korea), Jinhwe KWEON (GNU, Korea), Youngwoo NAM (KAU, Korea), Byeongsu KWAK (GNU, Korea)*	**HiSST 2024 - 069** Analytical Model of Curved-shock Inverse Mach reflection *Chongguang SHI, Rongguang SU, Tao ZHANG, Chengxiang ZHU, Yancheng YOU (Xiamen Univ., China)*
HiSST 2024 - 250 Multidisciplinary Analysis Framework for The Mission Design of Reusable Space Transportation Re-Entry Vehicles *Federico TOSO, Giovanni MEDICI, Jacopo GUADAGNINI, Gabriele DE ZAIACOMO (Deimos Space S.L., Spain)*	**HiSST 2024 - 132** The Dynamic Test of the Longitudinal Stage Separation for the Parallel-staged Two-stage-to-orbit Vehicle in Shock Tunnel *Yue WANG, Yun Peng WANG (IMCAS, China)*	**HiSST 2024 - 371** Thermophysical Properties of a High Density Carbon/Carbon Composite to Ultra-High Temperatures *Marco ATTIA, Wyman ZHUANG (DST Group, Australia)*	
Lunch The Party Restaurant (B1, Exhibition Hall)			
Poster Presentation Side Lobby (2F)			

HSM 3	**T&E 3**	**M&S 3**	**GCS 1**
Dr. Aaron KOCH (DLR, Germany)	Dr. Marco MARINI (CIRA, Italy)	Dr. David Glass (NASA, USA)	Prof. Tao CHAO (HIT, China)
Dr. Hideyuki Taguchi (JAXA, Japan)	Dr. Jeroen VANDENEYNDE (ESA, Netherlands)	Mr. Ilan WEISSBERG (Israel Aerospace Industries, Israel)	Ms. Sunayna SINGH (DLR, Germany)
HiSST 2024 - 118 Comparison of Different Fidelity Approaches for the Coupled Aerothermodynamic Heating of Hypersonic Reentry Vehicles *Fynn BARZ, Marius FRANZE (DLR, Germany)*	**HiSST 2024 - 090** System Study of an Integrated Facility with Arc-Jet and Expansion Tube for Hypervelocity Testing with Ablating Spacecraft Models *Eric Won Keun CHANG, Tobias A. HERMANN (Univ. of Oxford, UK)*	**HiSST 2024 - 348** Development and Qualification Status of the CMC based TPS of Space Rider *Mario DE STEFANO FUMO, Giuseppe RUFOLO, Roberto GARDI, Roberto FAUCI, Angelo DE FENZA, Francesca PISANO, Giuseppe Maria INFANTE (CIRA, Italy), Lorenzo CAVALLI, Massimiliano VALLE (Petroceramics s.p.a, Italy)*	**HiSST 2024 - 072** Two Stage to Orbit using a Hypersonic First Stage and Horizontal Launch *Michael PALUSZEK, Christopher GALEA, Stephanie THOMAS (PSS, USA),*

APRIL 16 (TUE)

Room No.	205	201	202	203
Session	**HSA 5**	**HSA 6**	**PSC 5**	**PSC 6**
16:00-16:30	**HiSST 2024 - 083** Compressible Correction and Correlation of γ-Reθ Transition Model for High-speed Flows *Fan YUXIANG, Zhao RUI, Zhang XU (BIT, China)*	**HiSST 2024 - 318** Reduction of Pressure and Heat Load by Counter-flow Jet on a Blunt Body in Hypersonic Flow *Min Su HWANG, Hyoung Jin LEE (Inha Univ., Korea)*	**HiSST 2024 - 115** Experimental Study on the Propagation Characteristics of Rotating Detonation Engine by JISC Fuel Injector Configuration *In-hoi KOO, Keon-Hyeong LEE, Jeong-Yeol CHOI (PNU, Korea)*	**HiSST 2024 - 222** Experimental Investigation of the Global Equivalence Ratio Influence in a Hydrogen-fueled Supersonic Combustor *Eden Schiavinato de SOUZA, Lucas RIBEIRO, Leda VIALTA, Pedro MATOS, Luiz BARRETA, Giannino CAMILLO, Israel RÊGO, Lucas GALEMBECK, Dermeval CARINHANA JR (IAS, Brazil), Pedro LACAVA (ITA, Brazil)*
16:30-17:00	**HiSST 2024 - 269** Numerical Study of Turbulent Phenomena in Hypersonic Boundary Layers from the Presence of Protuberances and Cavities *Alan FLINTON, Jim MERRIFIELD (FGE Ltd, UK), Matthew MCGILVRAY, William IVISON (Univ. of Oxford, UK), Frederik JACOBS, Johan STEELANT (ESA ESTEC, Netherlands)*	**HiSST 2024 - 255** Analysing Convective Heat Transfer over a blunt cone across different gas environments *Sreejita BHADURI, Naveen KUMAR (IIT Kanpur, India), SLN DESIKAN (VSSC, India), Mohammed Ibrahim SUGARNO, Ashoke DE (IIT Kanpur, India)*	**HiSST 2024 - 174** Investigation of Wave Behaviour in Non-Premixed H2-Air Annular Rotating Detonation Combustor using Large-Eddy Simulations *Yuxiang LIM, Thommie NILSSON, Christer FUREBY (Lund Univ., Sweden)*	**HiSST 2024 - 236** Comparative Analysis of Rectangular-to-Elliptical Shape Transition (REST) intakes with Diverse Leading-Edge Profiles *Daegi YEOM, Hyeonseo LEE, Seongkyun IM (Korea Univ., Korea)*
17:00-17:30	Coffee Break Lobby (2F)			
17:30-18:00	**HiSST 2024 - 087** Effects of Aft Angle on the Non-equilibrium Flows over Double Cone at High Enthalpy *Dengke LI, Bo SUN, Chunliang DAI, Xiong CHEN (NJUST, China)*	**HiSST 2024 - 046** Multi-objective Shape Optimization of Earth Re-Entry Capsule With Aero-Thermal Analysis *Minsul LEE, Kyu Hong KIM (SNU, Korea), Hyoungjin KIM (KHU, Korea)*	**HiSST 2024 - 282** Numerical Investigation of Pulse Detonation Engine with Resonator Injection *Timothee HEMARD, Bayindir H SARACOGLU (VKI, Belgium)*	**HiSST 2024 - 091** Cavity-based Combustion Characteristics of a Mach 10 Scramjet *Hongbo LU, Hengyi WU, Jian LIN, Ruiting WANG, Feng JI, Xing CHEN (CAAA, China)*
18:00-18:30	**HiSST 2024 - 286** Direct Numerical Simulation Study on Pressure Amplification and Shock-boundary Layer Interaction *Yujoo KANG, Sang LEE (KAIST, Korea)*	**HiSST 2024 - 302** A Code-to-code Comparison of Hypersonic Sharp Cone-flares *Jimmy-John HOSTE (Destinus, Switzerland), Tobias ECKER, Chiara AMATO (DLR, Germany), Nicholas GIBBONS (UQ, Australia), Doyle KNIGHT (Rutgers Univ., USA), Fahri Erinç HIZIR, Tolga KÖKTÜRK (Aselsan, Turkey), Artemii SATTAROV, Olivier THIRY (Cadence Design Systems, Belgium), Jean-Pierre HICKEY (Univ. of Waterloo, Canada), Steven QIANG, Jim CODER (Penn State Univ., USA), Neil CASTELINO, Valerio VITI (ANSYS Inc., USA)*	**HiSST 2024 - 352** Numerical Study on the Characteristics of Detonation Wave Number in RDE *Mohammed N NEJAAMTHEEN, Bu-Kyeng SUNG, Jeong-Yeol CHOI (PNU, Korea)*	**HiSST 2024 - 114** Study on Equal-Intensity-Distribution Configuration of External-Compression Multi-wave Curved Compression Flowfields *Wenguo LUO, Changkai HAO, Jianfeng ZHU, Yancheng YOU (Xiamen Univ., China)*

APRIL 16 (TUE)

204	103	104	105
HSM 3	**T&E 3**	**M&S 3**	**GCS 1**
HiSST 2024 - 189 TSTO Launcher for Small Satellites *Lakshmi Narayana Phaneendra PERI, Sasi Kiran PALATEERDHAM, Antonella INGENITO (La Sapienza, Italy), Francesco MARGANI, Luca ARMANI (GAUSS Srl, Italy)*	**HiSST 2024 - 102** Heterodyne Dual Frequency Comb Laser Absorption Spectroscopy Measurements in Supersonic Combustion *Jan MARTINEZ SCHRAMM, Leni SCHMIDT (DLR, Germany)*	**HiSST 2024 - 233** Optical, Magnetic, and Structural Stability Analysis of PbS Nanoparticles using a Shock Tube *P SIVAPRAKASH, Surendhar SAKTHIVEL, Ki-Won KIM, Ikhyun KIM (Keimyung Univ., Korea)*	**HiSST 2024 - 167** Trajectory Optimization Method for Dual Mode Scramjet Engine Vehicle using a Unstart Informed Combustion Model *Jiwon SON, (SNU, Korea), Hyo Sang KO, Han-Lim CHOI (KAIST, Korea), Kwanjung YEE (SNU, Korea)*
HiSST 2024 - 374 Overview of the Hypersonic Atmospheric Flight KREPE-2 *Alexandre MARTIN, Seungyong BAEG, Raghava S.C. DAVULURI (Uinv. of Kentucky, USA),*	**HiSST 2024 - 261** Design and Implementation of Electronic Sub-systems for the STAJe- Phase 1 Payload *Sampada Vijay SHELAR, Allan PAULL (UQ, Australia)*	**HiSST 2024 - 031** Development of Ultra-High Temperature Ceramic Matrix Composites for Hypersonic Applications via Reactive Melt Infiltration and Mechanical Testing under High Temperature *Luis BAIER, Martin FRIESS, N. Hensch, Vito LEISNER (DLR, Germany)*	**HiSST 2024 - 279** Relative Navigation Implementation for the In-Air Capturing of a Winged Reusable Launch Vehicle *Sunayna SINGH (DLR, Germany), Briek LUYTEN, Marco SAGLIANO (DLR, Germany)*
Coffee Break Lobby (2F)			
HiSST 2024 - 088 Comparison of Models for Aerothermal Load Prediction using Coupled Trajectory Simulations of a High Lift Reentry Vehicle *Marius FRANZE, Fynn BARZ (DLR, Germany)*	**HiSST 2024 - 196** Flow Disturbances at Super-orbital Velocity using Spectral Analysis In Expansion Tube Hek-X *Masahiro FUJIWARA, Keisho ITO, Shun Dylan IZUMA, Honami TOYAMA, Shuto YATSUYANAGI, Hideyuki TANNO (JAXA, Japan)*	**HiSST 2024 - 055** C/C Material Densification by CVI Process: from Experimental to Simulating Results *Jonathan RAYNAUD (MBDA, France), Yann QUIRING, C. Cairey REMONAY (LRGP, France), G. BORNE, V. BONTEMPI (MBDA, France), E. SCHAER, R. FOURNET (LRGP, France)*	**HiSST 2024 - 145** Trade Study for the Hardware Design of an AI-Driven Rocket Engine Health Monitoring System: Key Insights and Suggestions *João MATIAS (EDGX, Belgium)*
HiSST 2024 - 141 Flyability Assessment and Trajectory Design for a Scramjet Hypersonic Experimental Vehicle *Antonio VITALE, Sara DI BENEDETTO, Marco MARINI (CIRA, Italy), Simone PIZZURRO, Roberto BERTACIN (ASI, Italy)*	**HiSST 2024 - 355** Expansion Tube Capabilities for Studying Boost-Glide Re-entry Conditions *Yuhui LIN, James J. WALLINGTON, Thien BUI, Toby VAN DEN HERIK, Christopher M. JAMES, (UQ, Australia), Eric Won Keun CHANG, Tobias A. HERMANN (Oxford, UK)*	**HiSST 2024 - 066** Tailored Directional Porosity in Ceramic Matrix Composites (CMC) for Hypersonic Applications *Fiona KESSEL, Martin FRIESS, Carolin RAUH, Alexander WAGNER (DLR, Germany)*	**HiSST 2024 - 288** HEXAFLY-INT Actuation System Test Bench Updates *Lucas GALEMBECK, Breno SILVA (DCTA, IEAV, Brazil), Pasquale MANZO, Carmelo STOLDER (Marotta S.R.L, Italy), Waldemar ROTÄRMEL(DLR e.V., Germany), Johan STEELANT(ESA-ESTEC, Netherlands)*

APRIL 17 (WED)

Room No.	205	201	202	203
08:00-08:30	**Chair's Meeting** Room 206 (2F)			
08:30-09:30	**Keynote Speech 4** Chair: Prof. Jeong-Yeol CHOI (Pusan National Unviersity, Korea) **Theories and Technologies of Detonation-driven Hypervelocity Shock Tunnels** *Prof. Zonglin JIANG (Institute of Mechanics, Chinese Academy of Sciences, China)*			
Session	**HSA 7**	**HSA 8**	**PSC 7**	**PSC 8**
Chairs	Dr. Jan MARTINEZ SCHRAMM (DLR, Germany)	Dr. Erik TORRES (Univ. of Minnesota, USA)	Prof. Je Ir RYU (New York Univ. Abu Dhabi, UAE)	Prof. Hyung Sub SIM (Sejong Univ., Korea)
	Dr. Aleksandr FIRSOV (JIHT RAS, Russian Federation)	Dr. Tamara SOPEK (UniSQ, Australia)	Dr. Jun LIU (NUAA, China)	Dr. Ravi PATEL (Eindhoven Univ. of Technology, Netherlands)
09:30-10:00	**HiSST 2024 - 057** Heat Transfer Characteristics of the Missile Radome Considering Flight Scenario *Sangbin HAN, Hyung Mo BAE, Jihyuk KIM (Yonsei Univ., Korea), Dongkyun LEE, Kyeongho LEE, Sunghwan YIM (LIGNex1, Korea), Hyung Hee CHO (Yonsei Univ., Korea)*	**HiSST 2024 - 290** Effects of Ultrafast Laser Energy Deposition on a Hypervelocity Boundary Layer *Laurent M. LE PAGE, Andrew CERUZZI (Univ. of Oxford, UK), Thomas L. J. BRAIN, Alexander J. RIELEY (QinetiQ Limited, UK), Tristan J. CRUMPTON (Univ. of Oxford, UK), James C. ROBSON, Matthew ECKOLD (QinetiQ Limited, UK), Matthew MCGILVRAY (Univ. of Oxford, UK)*	**HiSST 2024 - 287** Numerical Study of Hydrogen Injection in Crossflow to Initiate Oblique Detonation Wave *Ashish VASHISHTHA, Rushikesh KORE (SETU, Ireland), Sasi Kiran PALATEERDHAM, Antonella INGENITO (Sapienza, Italy)*	**HiSST 2024 - 285** Influence of the Swing Angle on the Performance of Planar SSSL Nozzle *Rui LI, Jinglei XU, Haiyin LV (NUAA, China)*
10:00-10:30	**HiSST 2024 - 101** Convective Heat Flux Analysis for a Scramjet Engine *Ana Maria Pereira LARA, Israel REGO, Lucas A. G. Ribeiro, Pedro P. B ARAÚJO, Lucas Galembeck, Dermeval CARINHANA JR , Tiago ROLIM (IAS, Brazil)*	**HiSST 2024 - 096** Heat Transfer to a Flat Plate under Partially Dissociated Nitrogen Freestream Condition *Guangjing JU, Lin BAO (UCAS, China)*	**HiSST 2024 - 084** Experimental Study of Combustion Modes in PNU-DCSC with a micro-PDE *Min-Su KIM, Keon-Hyeong LEE, Eun-Sung LEE, Hyung-Seok HAN (PNU, Korea), Seung-Min JEONG (KARI, Korea), Bu-Kyeng SUNG, Jeong-Yeol CHOI (PNU, Korea)*	**HiSST 2024 - 252** Computational Parametric Study Evaluating Ramjet Combustor Geometry *David CERANTOLA, Daniel HANDFORD, Pradeep DASS (SES, Canada)*
10:30-11:00	**HiSST 2024 - 142** Separation Studies on Sphere and Cube Clusters in Mach 12 Flow *Dániel Gábor KOVÁCS, Guillaume GROSSIR (VKI, Belgium), Grigorios DIMITRIADIS (Univ. of Liège, Belgium), Olivier CHAZOT (VKI, Belgium)*	**HiSST 2024 - 144** Ablation Measurements on Aluminium Spheres in a Hyperballistic Tunnel *Flavien DENIS, Hermann ALBERS, Myriam BASTIDE, Christian REY, Serge GAISSER, Daniel ROTHER, Thierry STEIBLIN (ISL, France)*	**HiSST 2024 - 208** Modellings of Steady Shock Reflection with Chemical Heat Release and the Transition Criteria between Regular and Mach Reflections *Haoyang LI (IMCAS, China), Zijian ZHANG (PolyU, China), Chun WANG (IMCAS, China)*	**HiSST 2024 - 237** Operational Characteristics of a Liquid-fueled Regenerative Dual-mode Combustor Model with Small Inlet Flowpath Height *Inyoung YANG, Sanghun LEE, Kyungjae LEE, Yangji LEE (KARI, Korea)*
11:00-11:30	**Coffee Break** Lobby (2F)			

APRIL 17 (WED)

204	103	104	105
Chair's Meeting Room 206 (2F)			
HSM 4	**PSC 9**	**M&S 4**	**TEM 2**
Dr. Allan PAULL (UQ, Australia)	Dr. Tristan VANYAI (UQ, Australia)	Dr. Abhendra SINGH (Baylor Univ., USA)	Prof. Matthew MCGILVRAY (Univ. of Oxford, UK)
Dr. Jeroen VANDENEYNDE (ESA, Netherlands)	Prof. Hyunchang LEE (Kyungnam Univ., Korea)	Mr. Yann QUIRING (CNRS, France)	Prof. Hyung Ju LEE (PKNU, Korea)
HiSST 2024 - 294 e-DEAL Engine for a Mach 0-Mach 5 Cruiser *Francois FALEMPIN (MBDA, France)*	**HiSST 2024 - 117** Progress in the Development of a TPaSR Model for the Simulation of Combustion in Turbulent Supersonic Flows *Margot PRUVOST, Marc FERRIER (ONERA, France), Arnaud MURA (ENSMA, France)*	**HiSST 2024 - 040** A Multiscale Framework for Aero-thermo-chemical DFT/ CFD Simulation for Re- entry Environment *Jongkyung AN, Seunghwan Kwon, Jiseon Ahn, Rajkamal ANAND, Gun Jin Yun (SNU, Korea)*	**HiSST 2024 - 139** The Development of a Design Program for a High-speed Counter-flow Air Precooler *Xin ZHANG, Y. LU, XJ FAN (IMCAS, China)*
HiSST 2024 - 292 Conceptual Design and Multi-Objective Optimization of an Environmentally-Friendly High-Speed Civil Aircraft *Saeed HOSSEINI, Mohammad Ali VAZIRY-ZANJANY (AUT, Iran)*	**HiSST 2024 - 080** Numerical Investigation of Shock Induced Mixing Enhancement in Cavity-Based Scramjet Combustor *Tomoaki NARA, Chihiro FUJIO, Hideaki OGAWA (Kyushu Univ., Japan)*	**HiSST 2024 - 281** Modelling, Simulation and Testing of Inflatable Structures Applied to Re-entry in the EFESTO-2 Project *Roberto GARDI, Barbara TISEO, Gianluca DIODATI, A. SORRENTINO, Vincenzo QUARANTA (CIRA, Italy), Cedric JULIEN (ONERA, France), Giuseppe GUIDOTTI (Deimos Space S.L.U., Spain), Giuseppe GOVERNALE (Politecnico di Torino. Italy), Francesco PUNZO (ALI, Italy), Pietro PASOLINI (SRSED, Italy), Maxim DE JONG (TRLA, Canada)*	**HiSST 2024 - 152** Data Models for the Probabilistic Design of the Thermal Protection System of a Reusable Launch Vehicle Stage *Aaron Dexter KOCH, Jascha WILKEN, Marko ALDER (DLR, Germany)*
HiSST 2024 - 322 Achieving Optimal Designs for High-Speed Blunt Body vehicles: A Multi-Objective Approach with an Efficient Aerothermodynamic Prediction Program *Hoonjung YEO, Kyu Hong KIM (SNU, Korea)*	**HiSST 2024 - 334** Nitrogen Oxides Emission Estimation for a hydrogen-fuelled Dual-Mode Ramjet in the conceptual design phase *Valeria BORIO, Roberta FUSARO, Nicole VIOLA (Politecnico di Torino, Italy), Guido SACCONE (CIRA, Italy), Ginevra CIANCI (Politecnico di Torino, Italy)*	**HiSST 2024 - 064** CMCs for Missile Applications: Elaboration and NDI of EBCs at an Industrial Scale Jonathan RAYNAUD, Maxime LHUISSIER, Magali ROLLIN *Jonathan RAYNAUD, LHUISSIER Maxime, ROLLIN Magali (MBDA, France)*	**HiSST 2024 - 060** Numerical Simulation of Flow/Heat Transfer/Thermal Decomposition Characteristics of Supercritical Hydrocarbon Aviation Fuel in a Minichannel *Minseo LEE, Hyung Ju LEE (PKNU, Korea)*
Coffee Break Lobby (2F)			

APRIL 17 (WED)

Room No.	205	201	202	203
Session	**HSA 7**	**HSA 8**	**PSC 7**	**PSC 8**
11:30-12:00	**HiSST 2024 - 140** Assessment of Thermochemical Degradation Effects of Charring Material on the Wall Heat Flux during Atmospheric Re-Entry *Maxime LALANDE, Nicolas DELLINGER, Ysolde PREVEREAUD, Nathalie BARTOLI (ONERA, France)*	**HiSST 2024 - 028** Numerical Simulation of the Interaction between a Free-flying Ring and a Curved Shock Wave *Bodo REIMANN (DLR, Germany)*	**HiSST 2024 - 199** Ignition Delay Study of Liquid Nano-fuels for Application in Pulse Detonation Engines using a Shock Tube *Gagan GARG (GNU, Korea), Viren MENEZES, Upendra V BHANDARKAR, Bhalchandra P PURANIK (IIT Bombay, India), Rho Shin MYONG (GNU, Korea)*	**HiSST 2024 - 331** Thrust Enhancement of Rocket-Deployed Dual-Mode Ramjet Engine *Sangwook JIN, Haeseung JEONG, Minchan KWON, Juhyun BAE, Seokjin OH, Hojin CHOI, Jaehoon RYU, Suji LEE (ADD, Korea)*
12:00-12:30	**HiSST 2024 - 150** The Combined Effects of Large-Scale Roughness and Mass Injection in Hypersonic Flow *Wesley CONDREN, Raghul RAVICHANDRAN, Anthony FINNERTY, Chris HAMBIDGE, Matthew MCGILVRAY (Univ. of Oxford, UK)*	**HiSST 2024 - 143** Fluid and Heat Transfer Coupled Analysis of a Hypersonic Aircraft with TBCC *Aoto KIKUI, Akiko MATSUO, Eiji SHIMA (Keio Univ., Japan), Hidemi TAKAHASI, Hideyuki TAGUCHI, Shunsuke IMAMURA (JAXA, Japan)*	**HiSST 2024 - 036** Effect of Wall Curvature on Detonation Reflection in Combustion Chambers *Hao YAN, Xin HAN, Haochen XIONG, Chongguang SHI, Yancheng YOU (Xiamen Univ., China)*	**HiSST 2024 - 314** Experiments on High Speed Air-Breathing Propulsion for Sustainable Supersonic Flight *Friedolin Tobias STRAUSS, Konstantin MANASSIS, Marius WILHELM, Christoph KIRCHBERGER (DLR, Germany)*
12:30-13:30	**Lunch** The Party Restaurant (B1, Exhibition Hall)			
13:30-14:30	**Keynote Speech 5** Chair: Dr. Moritz ERTL (German Aerospace Center, Germany) **Optical Diagnostics in Supersonic Combustion Environments** *Prof. Hyungrok Do (Seoul National University, Korea)*			
14:30-17:00		**Workshop 1** High-Speed Air Intakes	**Workshop 2** High-Temperature Materials & Structures	**Workshop 3** Flight Platforms and Flight Testing
18:00-22:00	**Gala Dinner** Paradise Hotel Busan			

APRIL 17 (WED)

204	103	104	105
HSM 4	**PSC 9**	**M&S 4**	**TEM 2**
HiSST 2024 - 268 Multidisciplinary Optimization in Conceptual Design of Hypersonic Vehicles *Israel Da Silveira REGO, Ana Maria LARA, Brunno Campos Martins BARBOSA, Thiago ASSUNÇÃO, Lucas Alexandre RIBEIRO, Ronaldo CARDOSO, Tiago ROLIM, Marco Antonio SALA MINUCCI, Lucas GALEMBECK, Dermeval CARINHANA JR, Giannino PONCHIO CAMILLO*	**HiSST 2024 - 070** Investigation on Multi-channel Gliding Arc Plasma Enhanced Supersonic Ignition at Near Blowout Limit *Tiangang LUO, Jiajian ZHU, Mingbo SUN, Yifu TIAN, Minggang WAN, Yongchao SUN (NUDT, China)*	**HiSST 2024 - 330** STORT Hypersonic Flight Experiment CMC Thermal Protection System and Selected Flight Results *Thomas REIMER (DLR, Germany), Gisueppe Daniele DI MARTINO, Lucas DAUTH (Bayern-Chemie, Germany), Luis BAIER, Ali GÜLHAN, Florian KLINGENBERG, Dorian HARGARTEN (DLR, Germany)*	**HiSST 2024 - 214** Numerical Analysis of Non-equilibrium Effects using a Unified Solver *Seungyong BAEG, Raghava S. C. DAVULURI, Alexandre MARTIN (Univ. of Kentucky, USA)*
HiSST 2024 - 339 Preliminary Design of the Flight Control System for a Mach 5 Hypersonic Civil Passenger Aircraft *Oscar GORI, Simona LOCCISANO, Davide FERRETTO, Nicole VIOLA (Politecnico di Torino, Italy)*	**HiSST 2024 - 153** Development of an Empirical Correlation for Ethanol Jet in Crossflow Spray Profiles in Transonic and Supersonic Flows *Aubrey MCKELVY, James BRAUN, Guillermo PANIAGUA-PEREZ (Purdue Univ., USA), Etienne CHOQUET, Thierry ANDRÉ, François FALEMPIN (MBDA, France)*		**HiSST 2024 - 274** Large-Eddy Simulation of Supercritical Hydrocarbon Flows in a Heated Horizontal Circular Tube *Shuto YATSUYANAGI, Hideyuki TANNO (KSPC, Japan)*
Lunch The Party Restaurant (B1, Exhibition Hall)			
Workshop 4 Detonation			
Gala Dinner Paradise Hotel Busan			

APRIL 18 (THUR)

Room No.	205	201	202	203
08:00-08:30	**Chair's Meeting** Room 206 (2F)			
08:30-09:30	**Keynote Speech 6** Chair: Mr. Francois FALEMPIN (MBDA, France) **Industry / Agency Cooperation to Face Challenges in Research** *Dr. Gerald HAGEMANN (ArianeGroup, Germany)*			
Session	**HSA 9**	**HSA 10**	**PSC 10**	**PSC 11**
Chairs	Dr. Viola WARTEMANN (DLR, Germany)	Prof. Eunji JUN (KAIST, Korea)	Dr. Inyoung YANG (KARI, Korea)	Prof. Hyung Sub SIM (Sejong Univ., Korea)
	Prof. Tai Jin (Zhejiang Univ., China)	Prof. Zhi-Hui WANG (UCAS, China)	Dr. Marco MARINI (CIRA, Italy)	Dr. Christoph KIRCHBERGER (DLR, Germany)
09:30-10:00	**HiSST 2024 - 158** Application of HyperCODA to Hypersonic Flows Around Two-Dimensional Geometries *Chiara AMATO, Stefan FECHTER, Tim HORCHLER, Immo HUISMANN, Tobias ECKER (DLR, Germany)*	**HiSST 2024 - 186** A Standard Model for the Investigation of Aerodynamic and Aerothermal Loads on a Re-usable Launch Vehicle - Second Stage Geometry *Moritz ERTL, Tamas BYKERK (DLR, Germany)*	**HiSST 2024 - 253** Temperature Field Measurement of External Flash Boiling Spray in Region where Bubbles Generate and Grow *Hyunchang LEE (Kyungnam Univ., Korea)*	**HiSST 2024 - 350** Numerical Study of Reactive Flow dynamics in a Hydrogen-fueled Direct- Connect Scramjet Combustor depending on Number of Injector *Seung-Min JEONG (KARI, Korea), Jae-Eun KIM, Jeong-Yeol CHOI (PNU, Korea)*
10:00-10:30	**HiSST 2024 - 112** Transient Analysis of the Conjugate Heat Transfer Analysis of Scramjet Engine Inlet *Jae-Eun KIM, Jeong-Yeol CHOI (PNU, Korea)*	**HiSST 2024 - 162** Numerical Simulation of Multi-Temperature Thermochemical Non-Equilibrium Model Over High Enthalpy Flow *Chanho KIM (SNU, Korea), Yosheph YANG (KNU, Korea), Jae Gang KIM (Sejong Univ., Korea), Kyu Hong KIM (SNU, Korea)*	**HiSST 2024 - 121** Numerical Analysis of Confined Supersonic Combustion Fueled via a Fluidic Oscillator *Guillaume PELLETIER (ONERA, France)*	**HiSST 2024 - 184** Experimental Investigation of Combustion Mode Transitions in a Cavity-based Scramjet *Le LI, Jiajian ZHU, Minggang WAN, Yifu TIAN, Tiangang LUO, Qinyuan LI, Shuaijia SHAO, Mingbo SUN (NUDT, China)*
10:30-11:00	**HiSST 2024 - 159** Direct Numerical Simulation of Supersonic Reacting Mixing Layers *Nicholas GIBBONS, Lachlan WHYBORN, Vincent WHEATLEY (UQ, Australia)*	**HiSST 2024 - 170** Direct Numerical Simulation of Strong Shock-turbulent Boundary Layer Interaction *Yujoo KANG, Sang LEE (KAIST, Korea)*	**HiSST 2024 - 149** Characterizations of Combustion Destabilization in an Axisymmetric Supersonic Cavity-based Combustor *Qinyuan LI, Bo YAN, Mingbo SUN, Jiajian ZHU, Yifu TIAN, Minggang WAN, Tiangang LUO, Yongchao SUN (NUDT, Chian)*	**HiSST 2024 - 181** Numerical/Experimental Study Dual Injection in Supersonic Cross Flow *Sem DE MAAG (TNO, Netherlands), Jan Siemen SMINK, Edwin T.A. VAN DER WEIDE, Harry W.M. HOEIJMAKERS, Cornelis H. VENNER (Univ. of Twente, Netherlands)*
11:00-11:30	**Coffee Break** Lobby (2F)			

APRIL 18 (THUR)

204	103	104	105
Chair's Meeting Room 206 (2F)			
T&E 4	**T&E 5**	**O&E 1**	**TEM 3**
Prof. Gisu Park (KAIST, Korea)	Prof. Vincent WHEATLEY (UQ, Australia)	Prof. Jeong-Yeol CHOI (PNU, Korea)	Prof. Matthew MCGILVRAY (Univ. of Oxford, UK)
Dr. Sandy TIRTEY (Rocket Lab, Australia)	Dr. Ajmal MOHAMED (ONERA, France)	Dr. Aaron Dexter KOCH (DLR, Germany)	
HiSST 2024 - 050 Prediction of Static and Dynamic Derivatives of Damping Free-flight Model Using Image Processing Method *Eunju KIM, Soo Hyung PARK (Konkuk Univ., Korea)*	**HiSST 2024 - 259** Design of a Nozzle for Hypersonic Wind Tunnel with Optimized Hyperbolic Geometry *Masaki IIDA, Kohei SHIMAMURA (TMU, Japan)*	**HiSST 2024 - 116** A Contribution to Mitigate NOx and H2O Emissions for a Hydrogen-powered Hypersonic Vehicle *Daniel BODMER, Jacob JÄSCHKE (TUHH, Germany), Florian LINKE (DLR, Germany), Volker GOLLNICK (TUHH, Germany)*	**HiSST 2024 - 335** A Boundary Adaptive Sharpening Topology Optimization Method for High Reynolds Number Flow in Regenerative Cooling Structures *Xinlei LI, Kun WU, Xuejun FAN (IMCAS, China)*
HiSST 2024 - 154 Aero-Thermal Study and Experimental Characterization of a Novel Optical Probe for High Temperature Supersonic Flows *Ignacio LASALA_AZA, Aubrey MCKELVY, Guillermo PANIAGUA-PEREZ (Purdue Univ., USA), Etienne CHOQUET, Thierry ANDRÉ, François FALEMPIN (MBDA, France)*	**HiSST 2024 - 377** Development of Neuromorphic Imaging Spectroscopy for Hypersonic Flight Observation *Tamara SOPEK, Fabian ZANDER, Byrenn BIRCH, David BUTTSWORTH (UniSQ, Australia)*	**HiSST 2024 - 344** Analytical Formulations for NOx Emissions Prediction of a SABRE Engine *Fabrizio BORGNA, Valeria BORIO, Roberta FUSARO, Nicole VIOLA (Politecnico di Torino, Italy), Guido SACCONE (CIRA, Italy)*	**HiSST 2024 - 358** The effect of sintering condition on the properties and transpiration cooling performance of porous Ni-based superalloy *Jukyoung SHIN, Junhyeon BAE, Tae Young KIM (SeoulTech, Korea)*
HiSST 2024 - 321 Nozzle Flow Characterization of the SNU Hypersonic Shock Tunnel *Jinyoung KIM, Jinhwi KIM, Jungmu HUR, Bok Jik LEE, In Seuck JEUNG (SNU, Korea)*	**HiSST 2024 - 068** Establishment of Free Piston Type Expansion Tunnel *Honhar GUPTA, Jithin SREEKUMAR, Mohammed Ibrahim SUGARNO (IIT Kanpur, India)*	**HiSST 2024 - 360** Methods and Tools for Chemical Emissions Prediction for Space Launchers *Alessio RICCA, Valeria BORIO, Roberta FUSARO, Nicole VIOLA (Politecnico di Torino, Italy), Guido SACCONE (CIRA, Italy)*	**HiSST 2024 - 067** Experimental Investigation of Film Cooling Effectiveness using Different Coolant Gases in Hypersonic Flows *Jithin SREEKUMAR, Talluri VAMSIKRISHNA , Honhar GUPTA, Mohammed Ibrahim SUGARNO (IIT Kanpur, India)*

Coffee Break Lobby (2F)

APRIL 18 (THUR)

Room No.	205	201	202	203
Session	**HSA 9**	**HSA 10**	**PSC 10**	**PSC 11**
11:30-12:00	**HiSST 2024 - 078** Development and Verification of Nonequilibrium Hypervelocity Reacting Flow Modeling in Open Source Framework *Kun WU, Yu AO (IMCAS, China), Yuting JIANG (Hefei Zhongke Chongming Tech, China), Jianwen LIU (Beijing Power Machinery Institute, China), Xuejun FAN (IMCAS, China)*	**HiSST 2024 - 231** Verification of Nonequilibrium Chemistry Model for Hypersonic Computational Fluid Dynamics against First-principles Molecular-dynamics Simulations *Erik TORRES, Thomas E SCHWARTZENTRUBER (UMN, USA)*	**HiSST 2024 - 185** Investigation of Mixing and Combustion in Supersonic Flows *Sasi Kiran PALATEERDHAM, L N PHANEENDRA PERI, Antonella INGENITO (Sapienza, Italy), Gautam CHOUBEY (NIT Silchar, India)*	**HiSST 2024 - 351** Numerical Investigation on the Flow Dynamics of Interaction between Two Liquid-liquid Bi-swirl Injectors *Vishnu NATARAJAN, Jongsu OH, Jeong-Yeol CHOI (PNU, Korea)*
12:00-12:30	**HiSST 2024 - 105** Numerical Calculations of Hypersonic Nonequilibrium Flowfields Over a Sphere Using hy2Foam CFD Software *Jianshu WU, Michiko Ahn Furudate (CNU, Korea)*	**HiSST 2024 - 164** Rapid Design Method for Planform-customized Waveriders Based on the Second-order Curved Shock Theory *YiQi Tang, Zhancang Hu, Xiaoting Ding, Xiaogang Zheng, Chongguang Shi, Yancheng You (Xiamen Univ., China)*	**HiSST 2024 - 151** Longitudinal Acoustic Field in a Two-Phase Ramjet: Numerical Simulation and Acoustics Model *Erwin BEKAERT, Aurelien GENOT, Thomas LE PICHON (ONERA, France), Thierry SCHULLER (IMFT, France)*	**HiSST 2024 - 293** High Density Energy Particles as a Solid Fuel for Ramjet Applications *Sasi Kiran PALATEERDHAM, Abdul RAHMAN (Sapienza, Italy), Sri Nithya MAHOT TAMANANDA (Crescent Institute), Yash PAL (HITS, India), (Sapienza, Italy)*
12:30-13:00		**HiSST 2024 - 241** An Exploration of Adjoint-based Optimization for Hypersonic Vehicle- and Propulsion Design *Carola Rovira SALA, Marc Famada VIZCAINO, Alberto Simon FELIX (Cranfield Univ., UK), Ambara BERNABEU-VAZQUEZ (Destinus SA, Switzerland), Bart VAN HOVE (Destinus Spain S.L., Spain), Tamas Istvan JOZSA (Cranfield Univ., UK), Jimmy-John O.E. HOSTE (Destinus Spain S.L., Spain)*	**HiSST 2024 - 349** Spray Characteristics of High Energetic Powder Added Low-Temperature Gel Fuel Using Pressure Swirl Injector *Dong-Geun LEE, Sul-Hee KIM, In-Woong LEE, Dong-Hee LEE, Hee-Jang MOON (KAU, Korea)*	**HiSST 2024 - 232** Extension of the Lean Blow-off Limit in the Scramjet Combustor by the Multi-channel Gliding Arc Plasma *Rong FENG, Zhipeng MENG, Jiajian ZHU, Bo WANG, Mingbo SUN, Xiaoqing CHEN, Chao DING (National Innovation Institute of Defense Technology, China)*
13:00-14:30	**Lunch** The Party Restaurant (B1, Exhibition Hall)			
14:30-15:30	**Keynote Speech 7** Chair: Dr. Huan LIAN (Institute of Mechanics, Chinese Academy of Sciences, China) Impact of surface roughness on hypersonic boundary-layer transition: from asymptotics to numerics *Prof. Ming DONG (Institute of Chinese Academy of Sciences, China)*			
Session	**HSA 11**	**HSA 12**	**PSC 12**	**HSM 5**
Chairs	Dr. Chris JAMES (UQ, Australia)	Dr. Nicholas GIBBONS (UQ, Australia)	Dr. Moritz ERTL (DLR, Germany)	Prof. Ali GÜLHAN (DLR, Germany)
	Dr. Minkwan KIM (Univ. of Southampton, UK)		Dr. Marc FERRIER (ONERA, France)	Dr. Antonio VITALE (CIRA, Italy)
15:30-16:00	**HiSST 2024 - 305** Evaluation of the Particle-based Bhatnagar-Gross-Krook Method in Hypersonic non-Equilibrium Flows *Woonghwi PARK, Eunji JUN (KAIST, Korea)*	**HiSST 2024 - 045** Shock Wave Structure and Surface Pressure Prediction Using Deep Learning Model *Min Hyun HAN, Soo Hyung PARK (Konkuk Univ., Korea)*	**HiSST 2024 - 295** Eliminating Atomic Oxygen from RST Nozzle Simulations *Tristan VANYAI, Nicholas GIBBONS (UQ, Australia)*	**HiSST 2024 - 113** Aerothermal Loads Analysis of ReFEx by coupled CFD Calculations *Marius FRANZE, Viola WARTEMANN, C. MERREM, Henning ELSÄSSER, Tobias RUHE, Thino EGGERS, Hendrik WEIHS (DLR, Germany)*

APRIL 18 (THUR)

204	103	104	105
T&E 4	**T&E 5**	**O&E 1**	**TEM 3**
HiSST 2024 - 103 Numerical Performance Assessment of Vitiated Air Heater for DCSC Test Facility by 3D LES *Bu-Kyeng SUNG, Seung-Min JEONG, Min-Su KIM, Jeong-Yeol CHOI (PNU, Korea)*	**HiSST 2024 - 225** Development of a Free Jet Test Facility Aiming at Preliminary Validating Aeropropulsive Balance Prediction Methodology for Hypersonic Airbreathing Vehicles *Francois FALEMPIN, Alexandra DUARTE ANTONIO, Maxime LECHEVALLIER, Quentin MOULY, Julien LEFIEUX, Etienne CHOQUET, Quentin CHANZY (MBDA, France)*	**HiSST 2024 - 108** Scaling Effects on the Ignition Process in a Single-side Expansion Scramjet Combustor *Peiyi LI, Zun CAI, Yanan WANG, Quanqi WANG, Taiyu WANG, Hongbo WANG, Mingbo SUN (NUDT, China)*	**HiSST 2024 - 357** An Experimental Investigation on Geometry Type of Microchannel Heat Sinks to Ensure Flow Stability of Boiling Heat Transfer *Taeho CHOI, Tae Young KIM (SeoulTech, Korea)*
HiSST 2024 - 260 Development of Millimeter Wave Plasma Interferometry for the Measurement of Precursor Electron Density *Yosuke KUROSAKA, Kohei SHIMAMURA (TMU, Japan)*	**HiSST 2024 - 276** Multi-Temperature Modelling of High-Enthalpy T4 Shock Tunnel Nozzle Flows *Robert WATT, Rowan GOLLAN, Nicholas GIBBONS (UQ, Australia)*		**HiSST 2024 - 313** Effectiveness-NTU model for PCM-Compact Heat Exchanger Performance Prediction *Julie FRANK, Duncan BORMAN, Amirul KHAN, Jon SUMMERS (Univ. of Leeds, UK), Evaldas GREICIUNAS (Ignitis, Lithuania)*
HiSST 2024 - 075 Force Measurement in Shock Tunnel Tests Based on Deep Learning *Shaojun NIE, Yunpeng WANG (IMCAS, China)*			**HiSST 2024 - 107** Study of Liquid-vapor Phase Change Process inside Porous Cooling Device for Hypersonic Vehicle *Rui MA, Shibin LI, Zhongwei WANG, Lin WANG, Lei ZHANG (NUDT, China)*

Lunch The Party Restaurant (B1, Exhibition Hall)

HSM 6	T&E 6	PSC 13	HFH 2
Dr. Luke DOHERTY (Univ. of Oxford, UK)	Prof. Jeong-Yeol CHOI (PNU, Korea)	Dr. Tim ROOS (TNO, Netherlands)	Prof. LIANG WANG (Tsinghua Univ., China)
Dr. Martin SIPPEL (DLR-SART, Germany)		Dr. Ravi PATEL (Eindhoven Univ. of Technology, Netherlands)	
HiSST 2024 - 207 The HYPLANE Spaceplane *Gennaro RUSSO, Claudio VOTO (DAC, Italy)*	**HiSST 2024 - 168** Experimental Measurements on Tekna"PlasmaSonic" High Enthalpy Ground Testing Facilities using 350 kW ICPT Plasma Torch to Reproduce Re-entry Conditions of Space Vehicles *Yazid LAKAF, Siwen XUE, Eric BOUCHARD (Tekna, France)*	**HiSST 2024 - 239** Simulation of DC gliding arcs for supersonic combustion: influence on O2/H2 ignition *Ancelin ROCAMORA, Fabien THOLIN, Aymeric BOURLET, Julien LABAUNE, (ONERA, France), Christophe LAUX (CNRS, France)*	**HiSST 2024 - 223** Influence of Spanwise Wall-Vibration on Bypass Transition in Hypersonic Boundary Layers *Qinyang SONG, Ming DONG (IMCAS, China), Lei ZHAO (Tianjin Univ., China)*

APRIL 18 (THUR)

Room No.	205	201	202	203
Session	**HSA 11**	**HSA 12**	**PSC 12**	**HSM 5**
16:00-16:30	**HiSST 2024 - 209** Numerical Study on the SWBLI Induced Flow Unsteadiness Characterization in a Hypersonic Backward Facing Step *Vignesh P, Mohammad Ibrahim SUGRANO (IIT Kanpur, India)*	**HiSST 2024 - 307** Particle-based Simulation of Solid Rocket Plume at High Altitude *Yeongho SHIN, Eunji JUN (KAIST, Korea)*	**HiSST 2024 - 341** A Numerical Simulation on the Unsteady Flow in a GCH4-GOx Small Thrust Chamber *Hong Yeong PARK, Yun Hyeong KANG, Chang Han BAE, Jeong Soo KIM (PKNU, Korea)*	**HiSST 2024 - 161** Local Surface Inclination Method Calculations for the HEXAFLY-INT Vehicle *Pedro Paulo BATISTA DE ARAUJO (ITA, Brazil), Roberto YUJITANAKA, Fabio Henrique EUGENIORIBEIRO, Andre Carlos FRAILEJUNIOR, Angelo PASSARO, Lucas GALEMBECK, Giannino Ponchio CAMILLO, Dermeval CARINHANA JR (IAS, Brazil), Johan STEELANT (ESA-ESTEC, Netherlands)*
16:30-17:00	**HiSST 2024 - 258** High-Fidelity Aerothermoelastic Analysis of Hypersonic Vehicle using Fluid Solid Interface *Muhammad Danyal KAILANI, Naveed AHMED, Hafiz Sana Ullah BUTT (CESAT, Pakistan)*	**HiSST 2024 - 048** Comparison of Focker-Planck and CFD simulations of the RFZ-ST2 Upper Stage *Leo BASOV, Moritz ERTL, Tamas BYKERK (DLR, Germany)*	**HiSST 2024 - 218** Mechanisms for Combustion Instability by Micro-Rocket Torch in Scramjet Combustor based on Dynamic Mode Decomposition *Shinichiro OGAWA (OMU, Japan)*	**HiSST 2024 - 190** Ram-accelerator for Future Low-orbiting Operations *Daniele DI MARTINO, Elisa DI PAOLA (Unvi. of Rome, Italy), Vincenzo ALLEGRA (Thales Alenia Space, Italy), Emanuele RUA (Power and Electronics Subsystem Engineer Rome, Italy), Abdul R., Phanindra PERI, Antonella INGENITO (La Sapienza, Italy), Luana Georgiana STOICA, Alessandro DI MARCO (Unvi. of Rome, Italy)*
17:00-17:30	Closing			

APRIL 18 (THUR)			
204	103	104	105
HSM 6	**T&E 6**	**PSC 13**	**HFH 2**
HiSST 2024 - 323 Sensitivity Derivatives of a Low-Order Integrated Scramjet Propulsion Model for Gradient-Based Co-Design MDAO *Amir MITTELMAN, Kieran MACKLE, Rowan GOLLAN (UQ, Australia), Ingo JAHN (UniSQ, Australia)*	**HiSST 2024 - 251** Calibration of the MBDA-Subdray Hypersonic Wind Tunnel n°5 *Alexandra Duarte ANTONIO, Quentin MOULY, François FALEMPIN (MBDA, France), Gautier VILMART, Christophe BROSSARD (ONERA, France)*	**HiSST 2024 - 194** Simulation of The Mixing of a Supersonic Air Flow with a Transverse Jet under The Conditions of Pulse-Periodic Local Heating *Aleksandr A. FIRSOV, Luka S. VOLKOV (JIHT RAS, Russian Federation)*	**HiSST 2024 - 247** High Performance Wall Heat Flux Surrogate Models for Vehicles/Capsules Design Activities and Space Debris Ground Risk Estimation – Review of Onera Recent Developments *Ysolde PREVEREAUD (ONERA, France)*
	HiSST 2024 - 092 Laser Ablation Experiment of Aluminum Alloy in Ma6 Air Crossflow *Jian LIN, Xing CHEN, Hongbo LU (CAAA, China)*		**HiSST 2024 - 052** Asymptotic Analysis of Heat and Mass Transfer Performance of a Microscale Wavy Wall *Zhi-Hui WANG, Hui-Jun GAO (UCAS, China)*
Closing			

POSTER PRESENTATION SCHEDULE

DATE&TIME 14:00 - 14:30, April 16 (Tue)
LOCATION Side Lobby (2F), Convention Hall

POSTER NO.	PAPER NO.	PAPER TITLE	AUTHORS
PS 01	HiSST 2024 - 172	A Design Method for All-movable Rudder Structure with Lattices and Stiffeners by Thermo-elastic Topology Optimization under Mass Constraints	*Yang LI, Tong GAO (NPU., China)*
PS 02	HiSST 2024 - 085	Sizing Optimization of Fixed Cross-Section of Combustor in Ramjet Engine for Hypersonic Transport Considering Trajectory	*Yingchen LIU, Feng GUO, Jianfeng ZHU, Yancheng YOU (Xiamen Univ., China)*
PS 03	HiSST 2024 - 283	Ignition and Combustion Characteristics of Supersonic Combustor with a Simulation of Altitude Condition	*Hojin CHOI, Jong-Ryul BYUN, Sangwook JIN, Jaewon KIM, Dongchang PARK (ADD, Korea)*
PS 04	HiSST 2024 - 043	Design and Analysis of Double Design Point Inward-turning Inlet with Osculating Method	*Zejun CAI, Xiaogang ZHENG, Waner HU, Zhancang HU, Chengxiang ZHU, Yancheng YOU (Xiamen Univ., China)*
PS 05	HiSST 2024 - 254	A Computational Study on Surface Chemistry of Silane-Coated Aluminum Nanoparticles by Reactive Molecular Dynamics Simulations	*Hyung Sub SIM (Sejong Univ., Korea), Sungwook HONG (CSU, USA, Chang-Min YOON (Hanbat National Univ., Korea)*
PS 06	HiSST 2024 - 210	A Study on Air Plasma Characteristics Through LIBS: Spectral Identification and Temperature Estimation	*Hari Prasath M, Amar GHAR, Honhar GUPTA, Priyanka CHAVAN, Mohammed Ibrahim SUGARNO (IIT Kanpur, India)*
PS 07	HiSST 2024 - 238	Numerical Solution of Transpiration Cooling Method in Hypersonic Laminar Flow using the Kinetic Theory Model	*Davoud HOSSEINZADEH(Keimyung Univ., Korea), Esmail LAKZIAN (Hakim Sabzevari Univ., Iran / Andong National Univ., Korea), Hassan Saad LFIT (Univ. Maryland, USA), Ikhyun KIM (Keimyung Univ., Korea)*
PS 08	HiSST 2024 - 073	Development of the Surrogate Model for Combustion of Diesel by Extension of the Naphthene Basis Model	*Mehdi ABBASI, Ali NATEGHI (University of Tehran), Saeed HOSSEINI (Amirkabir Univ. of Technology, Iran)*
PS 09	HiSST 2024 - 035	Linear Quadratic Pursuit and Evasion Differential Game Guidance Strategy with Obstacle Avoidance	*Xintao WANG, Ming YANG, Ping MA, Tao CHAO (Harbin Institute of Technology, China)*

POSTER NO.	PAPER NO.	PAPER TITLE	AUTHORS
PS 10	**HiSST 2024 - 098**	Guidance Law Based on the Sliding Mode Control with Impact Angle Constrained	*He DU, Tao CHAO, Ming YANG, Songyan WANG (Harbin Institute of Technology, China)*
PS 11	**HiSST 2024 - 216**	Re-entry Survivability Analysis of Aluminum Oxide with Surface Roughness Considerations	*Seong-Hyeon PARK (EPFL, Switzerland), Yosheph YANG (KNU, Korea), Ikhyun KIM (Keimyung Univ., Korea)*
PS 12	**HiSST 2024 - 234**	Effect of Shock Wave Flows on Ce-BaTiO3 Nanoparticles for Photocatalytic Applications	*P. SIVAPRAKASH, Surendhar SAKTHIVEL, S. ARUMUGAM, Ikhyun KIM (Keimyung Univ., Korea)*
PS 13	**HiSST 2024 - 032**	Three-dimensional Curved Conical Shock Wave/plate Boundary Layer Interactions	*Jianrui CHENG, Chongguang SHI, Xiaogang ZHENG, Chengxiang ZHU, Yancheng YOU (Xiamen Univ., China)*
PS 14	**HiSST 2024 - 166**	Experimental Study of the Propagation Characteristics of Heated Air-Ethylene Rotating Detonation Wave in a Hollow Combustor	*Zhipeng SUN, Yue HUANG, Anjia SONG, sijia GAO (Xiamen University, China)*
PS 15	**HiSST 2024 - 173**	Theoretical Analysis of Interaction between Rotating Detonation Wave and Upstream Flow Field	*Sijia GAO, Yue HUANG, Yancheng YOU (Xiamen Univ., China)*
PS 16	**HiSST 2024 - 278**	Design and Characterization of a 6-in high-enthalpy Impulse Test Facility	*Youngjin JUN, Seongkyun IM (Korea Univ., Korea)*
PS 17	**HiSST 2024 - 177**	Measurement Method of Thermal Environment of Reentry Capsule	*Guangsen JIA, Dapeng YAO, Xin JIN, Jian LIN, Nong CHEN (CAAA, China)*
PS 18	**HiSST 2024 - 359**	Study on modified Crocco's model for thermodynamic calculation for Dual Mode Ramjet Engine	*H.J. NAMKOUNG (Hyundai-Rotem Company, Korea)*
WiPP 01	**HiSST 2024 - 376**	Subsonic Combustion Test of Dual Mode Scramjet Combustor	*Kyungjae LEE, Inyoung YANG, Sanghun LEE, Yangji LEE (Korea Aerospace Research Institute, Korea)*
WiPP 02	**HiSST 2024 - 379**	Plasma-assisted Ignition-stabilized Combustion (PAISC), a Solution Looking for an Application	*Ravi PATEL, Nico DAM, Sander NIJDAM, Jeroen VAN OIJEN (Eindhoven Univ. of Technology, the Netherlands)*

WORKSHOP

Our primary goal is to ignite engaging discussions among experts and conference attendees about the key elements that require attention in the short, medium, and long term. We'll delve into fundamental research, cutting-edge technologies, and practical applications, addressing critical issues and technical challenges along the way. Together, we'll chart a course for the future to ensure successful implementation.

Workshop Topics

DATE&TIME 14:30 - 17:00, April 17 (Wed)

High-Speed Air Intakes

Room 201 (2F)

Organizers: Dr. Michael SMART (Hypersonix, Australia), Dr. Ali GÜLHAN (DLR, Germany)

This workshop is concerned primarily with the design of compression systems for ramjet and scramjet engines. Efficient combustion of fuel requires that airflow be supplied to the combustor of these engines at a suitable pressure, temperature, and mass flow rate. For both ramjet and scramjets the propel vehicles traveling at high speed and at altitudes in the airbreathing flight corridor, this requires significant compression and heating of the air.

The performance of ramjet and scramjet intakes can be described by two key parameters: 1) capability, or how much compression is performed, and 2) efficiency, or what level of flow losses does the intake generate during the compression process. Meaningful discussions of intake performance must include both parameters as, for example, a highly efficient intake can be very easily designed if it is required to do little compression.

There are numerous practical constraints on the compression level of a ramjet or scramjet intakes that must be considered in the design of an operational engine. The most important of these are 1) delivery of flow conditions for robust combustion, 2) operability limits related to intake starting and boundary-layer separation, 3) aerothermal loads and high temperature structures and 4) nonequilibrium flow effects in the nozzle.

The focus of this workshop is on a number of topics that remain a focus for modern high speed intake design for operational ramjet and scramjet engines. These are:

- Intake starting phenomena
- Intake Buzz
- Aerothermal design
- Variable geometry

Discussion concerning these and related high speed intake topics will be most welcome.

High-Temperature Materials & Structures

Room 202 (2F)

Organizers: Mr. Chris KOSTYK (NASA-Langley, USA), Dr. Giuseppe RUFOLO (CIRA, Italy)

Materials and Structures are often viewed as one of the top technical challenges associated with high-speed flight. Correspondingly, there is a significant amount of work being performed in many countries. The rich diversity of topics and significant body of work provide fertile ground for the technical community to explore together to mutual benefit. Therefore, the Materials and Structures Workshop is intended to facilitate discussion regarding the top challenges, to be organized according to relevance to high-speed flight in the short-term (0-5 years), medium-term (5-15 years), and long-term (15+ years). A summary white paper will be published after the conference for the benefit of the technical community.

High-speed vehicle materials and structures must sustain thermal loads that include high temperatures, gradients, peak heating, and total heat load. The structures must also endure structural loads that can include quasi-static, dynamic, thermal expansion, and acoustic components. Additionally, chemical considerations from the flowfield and any propulsion components add another layer of complexity. The multidisciplinary analyses used to design the structures are challenging to validate, and often require a combination of ground and flight tests to verify performance. Inspection of the assemblies and composite material systems can prove challenging to verify build integrity and suitability for flight. Discussion concerning these and related materials and structures topics will be most welcome.

Topics include, but are not limited to:
Design and fabrication of high-speed vehicle structures
Single discipline (example: thermal, structural, or thermochemical) or multidisciplinary analyses to predict material, thermal, structural response to flight environment and vehicle loads
Single discipline or multidisciplinary ground testing of materials, subcomponents, components, vehicles
Flight testing of materials and structures for high-speed vehicles
Validation of thermal, structural, multidisciplinary analyses through ground or flight test
High-speed vehicle material and structure inspection, and flight certification

Flight Platforms and Flight Testing

Room 203 (2F)

Organizers: Dr. Sandey TIRTEY (Rocketlab, Australia), Dr. Su-Hee WON (Korea Aerospace Research Institute, Korea)

This workshop is dedicated to all different aspects that come into play during the conception of hypersonic flight experiments.

Although hypersonic in-flight testing is typically challenging and expansive, it offers unique characteristics and is complementary to ground testing in hypersonic facilities. The goal of flight testing could be to investigate real hypersonic phenomena than can be difficult to simulate in wind tunnels; to evaluate a system and the challenges associated with "long-duration flight environment" or to demonstrate the capabilities of an operational vehicle & launch system.

The investigation of some fundamental hypersonic phenomena can be difficult to perform in ground facility due to limitations in terms of model size, test duration and test conditions. Often, the only way to replicate all aspects in through flight testing. The development of different flight-test platforms and non-intrusive measurement techniques will be covered in this workshop.

Preparing for a long-duration (compared to wind tunnel) science-in-the-sky experiments or operational system demonstration requires the careful consideration of a variety of different aspects including:

Limitations of fundamental ground-test investigations and identification of needs e.g. size, test time, disciplines: e.g. aerodynamics, propulsion, materials & structures, thermal, GNC, vehicle concepts, instrumentation … and their interaction
Aerothermodynamic & propulsion performance required for potential flight platforms, e.g. captive or free-flying test objects, piggy back,…
Operations, mission scenario & compatible flight platform;
Flight vehicle development, including material & heat management definition.
Implementation of measurement techniques & control strategies definition;
Qualification, in-flight testing & potential reusability.
This workshop will discuss all these aspects, the latest associated advancements & challenges and identify the critical point and the next steps to be taken on the short and long term.

Detonation

Room 204 (2F)

Organizers: Prof. Yue HUANG (Xiamens University, China), Prof. Hyungrok DO (Seoul National University, Korea)

This workshop is dedicated to all the different aspects related to the fundamentals of detonation and the applications of detonative propulsion.

Detonation is characterized by the simultaneous propagation of a supersonic combustion wave and a leading shock wave. The coupling of these waves results in rapid changes in thermodynamic states, accompanied by fast energy release. Unlike subsonic deflagration, detonation is recognized as a pressure-gain, self-sustaining reacting flow. Detonative engines, utilizing pressure-gain combustion (PGC), have been explored as feasible alternatives to current propulsion employing pressure-constant combustion.

Different types of detonative engines have been proposed and developed over the past few decades. The detonation engines have drawn significant attention in recent years while underscoring the importance of sharing the latest research findings. Furthermore, the performance gains achievable through the detonative engines are still not fully understood. Conducting experimental measurements to analyze the detonation structure poses challenges due to the extreme conditions within the detonation engines. Therefore, discussions concerning these topics, as well as other related aspects relevant to detonation, are encouraged. A summary white paper will be published after the conference for the benefit of the technical community.

Goals and objectives:

To facilitate the discourse and exchange of ideas in detonation topics through discussion sessions, as well as highlight the latest progress and outstanding challenges in detonative propulsion;

To understand the advantages and disadvantages of the detonation cycle and the deflagration cycle under real engine operating conditions, as well as the differences and connections between pressure gain combustion and pressure gain of the combustor;

Strive to gain consensus on specific application scenarios based on detonation combustion.

Topics include, but are not limited to:

Recent developments in shock dynamics of detonation;

Recent progress and outstanding challenges in detonative propulsion (i.e., pulse detonation engine (PDE), rotating detonation engine (RDE), and oblique detonation engine (ODE));

New findings in detonation physics under real propulsion application conditions;

Experimental techniques for detonation in propulsion;

New analytical and computational methods for detonation.

SHORT ABSTRACTS

APRIL 15
MONDAY

ORAL PRESENTATION

High-Speed Aerodynamics and Aerothermodynamics 1 (HSA1)

Chairs: Dr. Moritz ERTL (DLR, Germany), Dr. Minkwan KIM (University of Southampton, UK)

HiSST 2024 - 202

Surface Catalytic Effect on Chemical Heat Flux using Direct Simulation Monte Carlo

Youngil KO, Eunji JUN

Korea Advanced Institute of Science and Technology (KAIST), Korea

Designing a Thermal Protection System (TPS) for re-entry vehicles requires numerical methods due to the difficulties in experimentally replicating the highly non-equilibrium flows. The Direct Simulation Monte Carlo (DSMC) method stands out for its effectiveness in capturing the non-equilibrium characteristics. This study assesses the effects of different molecular models and relaxation schemes within DSMC on the simulation of rarefied hypersonic flow around a 2D cylinder. Results show that the choice of molecular model and gas-phase relaxation scheme affects the surface heat flux and flowfield temperature prediction, respectively. Furthermore, a parametric analysis of the surface catalytic recombination in DSMC is conducted by adjusting the surface recombination coefficient, γ. The noncatalytic surface ($\gamma = 0$) and fully-catalytic surface ($\gamma = 1$) serve as the upper and lower bounds of the predicted total heat flux. Additionally, the chemical heat flux at the stagnation point increases with the surface recombination coefficient, due to the exothermicity of the recombination reaction, while translation heat flux remains nearly unaffected by surface catalysis.

Speaker: Youngil KO
Mr. Youngil Ko is a Graduate Student of the Department of Aerospace Engineering, Korea Advanced Institute of Science and Technology. He got his B.S. at the Department of Aerospace Engineering, Korea Advanced Institute of Science and Technology, Daejeon, Republic of Kore in 2023.

HiSST 2024 - 051

Radiation Computations and Ionisation Effects for Hypersonic Flow in Thermo-Chemical Nonequilibrium

Dominik JAMES, Christian MUNDT

Universität der Bundeswehr München (UniBw M), Germany

In this work, solutions for atmospheric reentries of two objects are generated: a generic hypersonic glide vehicle and the FIRE II capsule. Two flight points from the FIRE II trajectory are investigated: 1648s and 1636s. Solutions for the flow field are computed with an Euler method. The Euler method is in chemical or thermo-chemical nonequilibrium. An 11-species model allows for ionisation in the inviscid solution. Good agreement has been found for the temperatures and mass fractions along the stagnation line when comparing results to literature. The impact of thermo-chemical nonequilibrium and ions are discussed with regard to radiation.

Speaker: Dominik JAMES
Dominik James is a PhD student working for the University of the Federal Armed Forces in Munich, Germany. He completed his B. Sc. in Stuttgart, Germany; and his M.Sc. at Purdue University in the US.

HiSST 2024 - 126

Internal Flow Path Analysis of the Scramjet Hypersonic Experimental Vehicle

Oreste RUSSO[1], Pietro RONCIONI[1], Marco MARINI[1], Sara DI BENEDETTO[1], Giuliano RANUZZI[2], Simone PIZZURRO[2]

[1]Italian Aerospace Research Centre (CIRA), Italy
[2]Italian Space Agency (ASI), Italy

The paper focuses on the assessment of propulsive and combustion performances of a scramjet engine in hypersonic cruise conditions and its emission indexes for various species involved in the non-premixed combustion process. Nose-to-tail CFD analysis of the entire internal flow path (inlet, combustor and nozzle) are performed in flight-cruise configuration, for both fuel-off and fuel-on conditions, by using ANSYS FLUENT software with steady RANS modelling with available literature chemical schemes. The performance parameters, such as combustion efficiency and kinetic and thermodynamic quantities, revealed a significant improvement as well as the achievement of very high combustion efficiency by the end of the engine cycle is achieved.

Speaker: Pietro RONCIONI

Dr. Pietro Roncioni got his Degree in Aeronautical Engineering in 1994 and the Ph.D. in Thermo-Mechanical Engineering Systems in 2000, both at University of Naples "Federico II". He has been employed at CIRA since 2001 working in the fields of Aerodynamics, Aerothermodynamics, Propulsion and Combustion. He has been involved in several research projects, both national and international (USV, HYPROB, VEGA, VEGA-C, FLPP-IXV, LAPCAT-II, STRATOFLY). He is author or co-author of several scientific publications among conference papers and archive journals.

HiSST 2024-111

Assessment of Uranus Planetary Entry Conditions in the X2 Expansion Tube for Performing Infrared Thermography

Matthew UREN, Yu LIU, Chris JAMES, Richard MORGAN

The University of Queensland (UQ), Australia

A dedicated exploration mission of the ice giant planets has been prioritized as a key scientific objective by NASA and ESA to further understanding of their formation and atmospheric structure. In-situ measurements of the planetary atmosphere for giant planets has been successfully demonstrated with the Jupiter Galileo probe, however, there are significant uncertainties surrounding thermal loading and peak heating during giant planet entry. The usage of impulse ground test facilities, such as shock tunnels and expansion tubes, allows for the experimental simulation of planetary entry aerothermodynamics where such uncertainties can be investigated. Over the past decade, substantial development has gone into generating giant planet entry conditions at The University of Queensland's Centre for Hypersonics. Therefore, this work details the characterisation and assessment of Uranus peak heating entry conditions in the X2 expansion tube, and the suitability of the conditions for performing infrared thermography to obtain experimental heat flux data. Three test conditions were generated using the hypersonic facility analysis code PITOT3 and experimentally assessed in the X2 expansion tube using a Pitot pressure probe rake, a small fibre-coupled spectrometer, and a photodiode. Two of the conditions showed good repeatability across shots by assessment of the time-resolved Pitot pressure and photodiode measurements. Post shock properties were derived via PITOT3 using the experimental pressure measurements and an analytical thermal analysis was performed to predict the stagnation-point heat flux and subsequent surface temperature rise of a graphite test model. The convective heat flux calculations agreed well with predictions of ice giant entry heat flux from the literature and the surface temperature rise compared favourably to previous infrared thermography experiments in the X2 expansion tube. Whilst the test conditions appear suitable for the investigation of the Uranus peak heating trajectory point, the success of future experiments is dependent on the identification of a suitable waveband in the visible to IR spectrum and

appropriate selection of temporal and spatial resolution over the test flow and model, and this will be the prime focus of future work towards obtaining experimental heat flux data.

Speaker: Matthew UREN
Mr. Matthew UREN is an Aerospace Engineering PhD Candidate at The University of Queensland in the Centre for Hypersonics, Expansion Tube Laboratory.

HiSST 2024 - 125

Heat Flux Augmentation Caused by Surface Imperfections in Turbulent Boundary Layers

William IVISON[1], Chris J. HAMBIDGE[1], Matthew MCGILVRAY[1], Alan FLINTON[2], Jim MERRIFIELD[2], Johan STEELANT[3]

[1]University of Oxford, UK
[2]Fluid Gravity Engineering Ltd., UK
[3]European Space Agency (ESA-ESTEC), Netherlands

Aerodynamic heating of hypersonic vehicles is one of the key challenges needed to be overcome in the pursuit of sustained hypersonic flight. Small, unavoidable imperfections are always present on the surface of aircraft in the form of steps, gaps, and protuberances. These can lead to high levels of localised heat flux augmentation, up to many times the undisturbed level. Flat plate experiments have been carried out in the Oxford High Density Tunnel with the aim of characterising the heating effects caused by small scale surface features in turbulent boundary layers. The current work presents experimental heat flux augmentation data, an assessment of existing heat flux correlations, and introduces new engineering level correlations to describe heat flux augmentation for a range of surface geometries.

Speaker: William IVISON
William Ivison is a PhD candidate in the Hypersonics Group at the University of Oxford. His research focusses on high-speed aerothermodynamics, specialising in the effects of surface imperfections on heat flux and boundary layer transition.

High-Speed Aerodynamics and Aerothermodynamics 2 (HSA2)

Chairs: Dr. Bodo REIMANN (DLR, Germany), Prof. Rho Shin MYONG (Gyeongsang National University, Korea)

HiSST 2024 - 047

An Investigation of Internal Drag Correction Methodology for Wind Tunnel Test Data in a High-Speed Air-Breathing Vehicle using Numerical Analysis

Younghwan LEE[1, 2], Hyeon JIN[1], Min-Gyu KIM[1], Hyungrok DO[2]

[1]Agency for Defence Development (ADD), Korea
[2]Seoul National Univeristy (SNU), Korea

Accurate understanding of aerodynamic characteristics is critical for air vehicle design. This study applies the impulse-momentum theorem to estimate internal drag of an asymmetric air vehicle. Both computational fluid dynamics (CFD) and wind tunnel tests were employed. Numerical analysis using STAR-CCM+ was conducted across various Mach numbers, while wind tunnel tests were conducted under only specific Mach number conditions. The measured data from wind tunnel tests, which is considered representative, were compared with CFD plane-averaged values, indicating fairly good agreement. However, discrepancies arose when comparing CFD cell-averaged values with the plane-averaged values. To address this, a correction function was developed to describe the differences. It was observed that the ratio of internal drag coefficient from the cell-averaged values to that of the plane-averaged values followed an exponential function of Mach number. This approach allows wind tunnel data to be transformed into a form akin to cell-averaged values, enhancing internal drag estimation accuracy. Future research will explore additional methodologies to further refine and validate the proposed approach.

Speaker: Younghwan LEE
Younghwan Lee is a research engineer in Agency for Defense Development and also a part-time doctroal student in Seoul National Univsersity. He has been studied in the related field of intake aerodynamics and intake design.

HiSST 2024 - 079

Vibrational Non-equilibrium Effects in Compressed and Expanding Hypersonic High Enthalpy Flow

Jan MARTINEZ SCHRAMM, Georgii OBLAPENKO

German Aerospace Center (DLR), Germany

Atmospheric entry capsules shaped as spherically blunted, large apex-angle cones are widely used in space missions. Measurements in a hypersonic wind tunnel and numerical simulations on these types of capsules are performed. The comparing of the results of the experiments to the numerical simulation with respect to shock standoff distance and total drag allow for validation of the implemented physico-chemical models and the chemical relaxation rates in the numerical codes. The numerical reconstruction of the flow heavily depends on the accuracy of the assumed free stream used as an inflow conditions within the numerical simulations. The free stream of the wind tunnel experiments used as the inflow is obtained from numerical simulations of the hypersonic wind tunnel nozzle; here, the experimentally determined reservoir conditions of the wind tunnel nozzle determine the accuracy of the numerically determined freestream. Summarized we can state, that the measurements of the wind tunnel reservoir conditions drive the quality of the above mentioned validation process. The paper will present the work invested into determine the uncertainties of the validation process.

Speaker: Jan MARTINEZ SCHRAMM
- Dr.rer.nat. Physics at University of Göttingen in 2008
- Head of Spacecraft Department Institute of Aerodynamics and Flow Technology since 2021
- Experimental High Temperature Gas Dynamics

HiSST 2024 - 227

Numerical Study on Heat Fluxes in Hypersonic Flow over a 3D Sharp Cone

Soham SINHA, Mohammed Ibrahim SUGARNO

Indian Institute of Technology Kanpur (IIT Kanpur), India

The conical nose shape has long been a focal point of high-speed aerodynamic research. It serves as the foundation from which a multitude of general forebody designs, including waveriders, draw their inspiration. This study aims in investing the change in flow physics over a sharp cone as the angle of attack (AoA) is changed. This entails the presence of an attached conical shockwave in conjunction with the development of an attached boundary layer on the surface. Also due to this alteration, the heat transfer rate to the conical surface from the windward side to the leeward side will also get affected. The model used here is a 200mm slender cone with 8° semi-apex angle having a sharp leading edge. The notable flow features are change in shock angle, heat flux to the conical surface and the recirculation zone at the base of the cone with variation of AoA. Flow over the cone will be Laminar throughout its length. So, it will give an idea about the heat flux if the entire flow over the conical body can be maintained laminar. In this extended abstract, glimpse of work done on 8° angle of attack is presented showing the variation of heat flux in the axial and circumferential axis. Analysis of the boundary heat flux contour leads to the following observations: 1. The highest heat flux is concentrated near the tip of the cone, gradually diminishing in intensity as we move along the axial direction. 2. In the circumferential aspect, the maximum heat flux is situated at the base of the cone, gradually diminishing as we progress towards the upper surface. Work is still in progress and numerical results will be presented.

Speaker: Soham SINHA
Mr. Soham SINHA is currently pursuing a Master's degree in Aerospace Engineering with Aerodynamics as my specialization at the Indian Institute of Technology Kanpur, India. My work is on Numerical study on Heat Fluxes in Hypersonic flow over a Sharp 3D cone.

HiSST 2024 - 054

Analysis of the Cooling Performance of the Scramjet Regenerative Cooling Channel according to the Aspect Ratio using the Conjugate Heat Transfer Analysis

Jae Seung KIM, Song Hyun SEO, Kyu Hong KIM

Seoul National Univeristy (SNU), Korea

This study conducted a basic study on the cooling performance of the scramjet regeneration cooling considering the aspect ratio (AR) for the optimal design. The cooling performance according to the aspect ratio of the regenerative cooling channel was checked by reflecting the aerodynamic heating and combustion heat generated from the flow during the flight at Mach 6 for 600 seconds. The regenerative cooling channel inside the scramjet aircraft was reflected in one dimension, and the heat transfer model was applied to calculate the heat transfer coefficient. The heat transfer analysis method was verified by comparing it with the cooling channel experimental data, and finally, the cooling performance was compared considering the regenerative cooling channel AR of 1, 2, and 4.

Speaker: Jae Seung KIM
Dr. Jae Seung KIM is a Ph.D. candidate in Aerospace Engineering at Seoul National University. my research interests primarily focus on the conjugate heat transfer analysis of dual-mode ram/scramjet engines, modeling of supercritical fuels, and optimization of regenerative cooling channels.

HiSST 2024 - 053

Fluid-thermal-structural Coupled Study on Rudder Leading Edge with Porous opposing Jet in Hypersonic Flows

Shaliang LI, Bing LIU, Shibin LI, Wei HUANG, Lin WANG

National University of Defense Technology (NUDT), China

Hypersonic air rudders face extreme force/thermal environments, and opposing jet can improve the thermal environment in their stationing or leading edge regions. In order to understand the effects and mechanisms of porous opposing jet at rudder leading edges, a numerical simulation study is carried out, by using a two-way loose coupling method of fluid-thermal-structural. The drag reduction and heat prevention mechanisms of no jet and porous jet is comprehensively compared and analyzed. The results show that the introduction of the porous opposing jet change flow field at the leading edge of the air rudder, the bow shock is pushed outward, and its surge surface shows regular undulations. The porous opposing jet can provide a good effect in both drag reduction and thermal protection, which reduces the overall temperature of the rudder leading edge by about 20% and the heat flux by about 25%.

Speaker: Lin WANG
National University of Defense Technology, Doctor, focuses on fluid-thermal-structural coupled study of hypersonic vehicles.

Propulsion Systems and Components 1 (PSC 1)

Chairs: Prof. Yunghwan BYUN (Konkuk University, Korea), Prof. Antonella INGENITO (Sapienza, Italy)

HiSST 2024 - 025

A Numerical Study of Supersonic Intakes

Jimmy-John HOSTE[1], Bruno PIAZZA[2], Fernando MIRO-MIRO[3]

[1]Destinus SA, Switzerland
[2]Destinus Germany GmbH, Germany
[3]Destinus Spain S.L., Spain

In the context of supersonic propulsion, the intake plays a crucial role in providing the necessary compression and flow quality to the engine. CFD has become an affordable tool to leverage in such intake design, but in order to do so, it requires extensive validation. To this end, two supersonic intakes documented in the literature have been numerically studied in two-dimensional setups with the commercial software Simcenter STAR-CCM+. In the Mach 2.4 setup, generally good quantitative agreements with experimental wall pressure traces are observed. The Mach 1.9 Concorde intake demonstrates that two-dimensional simulations can be relied on for design tasks covering the different operation modes. However, three-dimensional domains should be considered to cover the full subcritical operation range and spillage characteristics adequately. In general, modifications in the turbulence settings for Menter's SST (2003) model have proven to be beneficial. This includes deactivating the dilatation compressibility correction, setting the a1 model constant to 0.355 and relying on a quadratic constitutive relation for the Reynolds stresses.

Speaker: Jimmy-John HOSTE

Jimmy-John is an Aerothermodynamics and Combustion Engineer at Destinus (www.destinus.ch), a Swiss start-up aiming to revolutionize hypersonic cargo transport. His present work targets the design and optimisation of high-speed aerospace vehicle systems based on CFD. Before joining Destinus, he worked as a postdoctoral researcher at CERFACS (2020-2021) and DLR (2018-2020). He completed his PhD in scramjet propulsion at the University of Strathclyde (2014-2018) in collaboration with the University of Queensland following a postgraduate degree in CFD at Cranfield University and an Aeronautical Engineering MSc from the Free University of Brussels

HiSST 2024 - 041

Verification of Variable Inlet Design through Wind Tunnel Test

Young Jin KIM, Hyoung Jin LEE

Inha University, Korea

Scramjet engines used for efficient flight in supersonic and hypersonic areas have the disadvantage of not generating thrust at subsonic and stationary conditions. Therefore, ramjet or scramjet engines are not used alone but in complex cycles such as TBCC(Turbine Based Combined Cycle) and RBCC (Rocket Based Combined Cycle) combined with turbine or rocket engines. In such an integrated propulsion system, a configuration design for a variable inlet is required since operation is essential in a wide range of Mach numbers. In this study, the required mass flow conditions of the TBCC aircraft were derived, and the shape design and detailed design procedures of the variable inlet satisfying them were presented. The maximum operating Mach number of the variable inlet was set to 7, and the shape of the variable suction port was designed using variable lamps and cowls to satisfy the required flow rate conditions for each Mach number. Boundary layer correction and computational analysis were performed on the designed shape. As a result of two-dimensional numerical simulation, it was confirmed that the mass flow rate flowing into the inlet satisfies the requirements. After that, a wind tunnel test was

performed by creating a reduction model for the variable inlet for Mach 2 and 7. The supersonic wind tunnel was used in Mach 2, and the hypersonic shock wave tunnel was used in Mach 7. In each test, the inlet performance analysis was performed through back pressure control and verification of the designed inlet shape. As a result of the wind tunnel test, it was verified that the shape of the inlet in each Mach number was carried out properly, and the starting characteristics according to the back pressure were confirmed.

Speaker: Young Jin KIM
Young Jin Kim is a Ph.D. student at Jet Propulsion Laboratory in Inha university. His research focuses on the supersonic and hypersonic inlets.

HiSST 2024 - 095

Preliminary Study of High-speed Variable Geometry Two-dimensional Inlet Design

Jun LIU, Xueju QIU, Huacheng YUAN

Nanjing University of Aeronautics and Astronautics (NUAA), China

In order to meet the thrust and mass flow requirements of the new concept aero-engine within the altitude range of 0-30 km and the Mach number range of 0-5, this paper proposes a new external compression method which consists of isotropic compression and ramp compression. Firstly, the inlet capture area is set as 2.0 m2 based on the engine airflow requirements, and the inlet aerodynamic schemes are designed at different design points (Ma2.5, Ma3.6, Ma5.0). The results indicate that inlet aerodynamic scheme for the design point Ma3.6 is the best. Secondly, the variable geometry scheme of the two-dimensional inlet within the Ma 0-5 range is studied. In order to improve the total pressure recovery coefficient of the inlet, the throat Mach number of the inlet is controlled within the range of Ma1.2-Ma1.5. The total pressure recovery coefficient of the design point inlet is 0.96 at throat section. The maximum total pressure recovery at aerodynamic interface plane reaches 0.70, which is 5.9% higher than the requirement. Finally, the velocity characteristics of the variable geometry inlet are studied. The operation range of the inlet is widen through adjusting the angle of the second compression ramp and the shoulder boundary layer suction. The results indicate that the inlet meets the requirement of aero-engine at a wide range.

Speaker: Jun LIU
I am a lecturer from Nanjing University of Aeronautics and Astronautics. My research interests are turbine-based combined-cycle inlet and aeroengine performance analysis.

HiSST 2024 - 242

Experimental Performance Evaluation of a Streamline Traced Inlet at Off-Design Conditions

Andrew PILKINGTON [1], Luke J DOHERTY [1], Chris J HAMBIDGE [1], Matthew MCGILVRAY [1], Tristan VANYAI [2], Vincent WHEATLEY [2]

[1]University of Oxford, UK
[2]The University of Queensland (UQ), Australia

Scramjet engines used as part of a multi-stage space access system must operate efficiently over a wide range of conditions. This paper describes experimental testing undertaken to evaluate the mass capture performance, self starting capability and back pressure limitations of a streamline-traced three dimensional inlet. Experiments were conducted in the University of Oxford High Density Tunnel. Instrumentation included fast-response surface pressure measurements along the inlet, and a novel back pressure/mass capture device suitable for accurate measurement of mass flow rate in short duration testing. Tests were performed at Mach 7 over a range of unit Reynolds numbers to evaluate the inlet.

Speaker: Luke J DOHERTY
Luke Doherty completed his Doctorate within the University of Queensland's Centre for Hypersonics in 2014. He is currently employed as Departmental Lecturer in High Speed Flows at the Oxford Thermofluids Institute, University of Oxford.

HiSST 2024 - 328

Numerical Study of Turbulent Combustion in High Mach Number Scramjet Engine with Thermodynamic Non-equilibrium Effect

Hai FENG[1], Tai JIN[1], Kun WU[2]

[1]Zhejiang University (ZJU), China
[2]Institute of Mechanics, Chinese Academy of Sciences (IMCAS), China

Thermodynamic non-equilibrium effect has a significant impact on hypersonic aircraft and must be taken into consideration in numerical computations. Numerical simulations of a Mach 12 flight condition scramjet engine were conducted using both thermodynamic equilibrium models and Park's dual-temperature non-equilibrium model. The results indicate that, compared to equilibrium state calculations, non-equilibrium effects lead to a rearward shift in the wave system position, resulting in a noticeable reduction in peak pressure between shock waves, with a more pronounced impact on the reaction flow. The non-equilibrium Ttr temperature field is generally similar to the equilibrium state. Thermodynamic non-equilibrium effects lead to a slight reduction in Ttr. In the non-equilibrium state, the combustion efficiency at the outlet section of the combustion chamber is higher, indicating that thermodynamic non-equilibrium effects enhance the extent of the reaction.

Speaker: Hai FENG
Mr. Hai feng is a PhD candidate at the School of Aeronautics and Astronautics, Zhejiang University. His research direction is Supersonic combustion non-equilibrium effects.

Propulsion Systems and Components 2 (PSC 2)

Chairs: Dr. Tim ROOS (TNO, Netherlands), Prof. Kun WU (IMCAS, China)

HiSST 2024 - 109

Feasibility Study of an Electric Supersonic Propeller

Jens KUNZE, Allan PAULL

The University of Queensland (UQ), Australia

An analysis of a supersonic propeller driven by an electric motor is performed. Recent and continuing progress in electric energy storage systems and electric motors as well as materials have opened up the design space for a large number of applications. So, too, for electrically powered flight. A propeller is the simplest method of converting electric energy into aerodynamic thrust. The analysis in this study is aimed at evaluating the predictive performance of a two dimensional and a quasi three dimensional model compared to fully three dimensional simulation results using computational fluid dynamics. Power efficiencies are calculated for a number of different propeller blades. The geometric features of particular interest are the shape of the leading and trailing edges, the thickness of the blade, its cross-sectional shape and the blade twist. The results show that, for the blades investigated here, the efficiencies predicted by the quasi three dimensional model match match the simulation results very closely for the smallest edge radius. Even the prediction by the two dimensional model is quite close to the magnitude of the blade efficiency, although it under predicts the rotational speed required to achieve it. For larger edge radii neither model makes good predictions.

Speaker: Jens KUNZE
Jens is a postdoc at the University of Queensland's Centre for Hypersonics working on electric supersonic propulsion. His main focus is the design of a propulsion system based on an electric propeller.

HiSST 2024 - 131

Off-Design Performance through Transient Simulations of an Expander-Type Air-Turbo-Rocket

Karel VAN DEN BORRE, F. PETTINATO, Bayindir Huseyin SARACOGLU

von Karman Institute for fluid dynamics (VKI), Belgium

Expander-type Air-Turbo-Rocket (ATR) engines combine the characteristics of rocket engines and conventional air-breathing Brayton cycles, which provide them with excellent performance in terms of specific thrust and impulse over a wide range of altitudes and flight Mach numbers. The maximum flight Mach number is extended compared to other turbine-based cycles by removing the turbine from the hot airflow path. This combination of properties makes them particularly well suited for high-speed supersonic aircraft or the air-breathing ascent stage of spaceplanes. This work re-examines architectures previously studied in on-design steady conditions by including the off-design behaviour in fully transient simulations. The implementation of the required control mechanisms to stabilise and regulate the engine is included, which allows for assessing the feasibility of a more practical engine implementation and for examining the operability margins along the acceleration phase of a high-speed cruiser aircraft.

Speaker: Karel VANDENBORRE
Karel Van den Borre received his Master of Science in Electromechanical Engineering at the Vrije Universiteit Brussels (VUB) in 2021. The year after, he graduated at the von Karman Institute for Fluid dynamics (VKI), obtaining a Research Master in Fluid Dynamics. Currently, he is serving as a joint PhD candidate in both the

Turbomachinery and Propulsion department at VKI and the FLOW research group at VUB. His primary research focuses on supersonic propulsion cycle modelling, reduced order modelling of combustion processes, and sustainable aviation fuels.

HiSST 2024 - 157

Conceptual Design of Hypersonic Combined Cycle Engines

Hideyuki TAGUCHI, Hidemi TAKAHASHI, Shunsuke IMAMURA, Sadatake TOMIOKA

Japan Aerospace Exploration Agency (JAXA), Japan

Conceptual design of hypersonic combined cycle engines is investigated. A pre-cooled turbojet engine and a scramjet engine are combined to a turbine-based combined cycle (TBCC) engine. The pre-cooled turbojet engine is assumed to be operated from Mach 0 to Mach 5. The scramjet engine is assumed to be operated from Mach 5 to Mach 6. The operating condition of the pre-cooled turbojet engine is confirmed using the results of propulsion wind tunnel test at Mach 4 flight simulating condition. A light weight mode change mechanism is proposed to change the engine cycle from the pre-cooled turbojet engine to the scramjet engine. A waverider shape airframe is designed and the flight performance is calculated for a hypersonic aircraft using the TBCC engine.

Speaker: Hideyuki TAGUCHI

Dr. Taguchi obtained his Doctorial degree at the University of Tokyo. He has worked for Japan Aerospace Exploration Agency (JAXA) from 1996. His current work is systems analysis on hypersonic airplanes and experiment of hypersonic jet engines.

HiSST 2024 - 193

Properties of Direct Current Discharge in a Supersonic Flow, and Its Application for Plasma-Assisted Combustion

Aleksandr A. FIRSOV, Anastasia S. DOBROVOLSKAYA, Dmitriy A. TARASOV, Roman S. TROSHKIN, Valentin A. BITYURIN, Aleksey N. BOCHAROV

Joint Institute for High Temperatures of the Russian Academy of Sciences (JITH RAS), Russian Federation

The thermodynamic properties, as well as distributions of gas-dynamic quantities in the region of interaction of a direct current discharge with a supersonic flow, were determined experimentally and using numerical modeling. A discharge with a current of 0.5-7 A and a discharge voltage of up to 2 kV is considered in longitudinal and longitudinal-transverse configurations in a flow with Mach number M=2, static pressure 22 kPa and gas temperature 170 K. For the longitudinal-transverse configuration, the dependences of the loop length and breakdown frequency on the current and interelectrode distance are determined. The mechanism of re-breakdown of a longitudinal-transverse discharge in a supersonic flow is presented. Recommendations for using such type of discharge for plasma-assisted combustion are discussed.

Speaker: Aleksandr A. FIRSOV

Aleksandr A. Firsov, Ph.D. Joint Institute for High Temperatures RAS, Moscow, Russia. Dec 2011 - Ph.D. in «Plasma physics» at Lomonosov Moscow State University, Faculty of Physics. Winner of the Moscow Government Prize for young scientists in 2017 in the field of mathematics, mechanics and computer science. Winner of the competition for the Russian Science Foundation grants (2017 (2 years project) and 2021 (3 years project)).

High-Speed Missions and Vehicles 1 (HSM 1)

Chairs: Mr. Lucas GALEMBECK (IAS, Brazil), Dr. Martin SIPPEL (DLR-SART, Germany)

HiSST 2024 - 027

Experimental Outdoor Activity on Sonic Boom Assessment of the STRATOFLY MR3 Scale Model

Giovanni FASULO[1], Sébastien HENGY[2], Bastien MARTINEZ[2], Luigi FEDERICO[1], Luciano DE VIVO[1], Marie ALBISSER[2], Andreas ZEINER[2]

[1] Italian Aerospace Research Centre (CIRA), Italy
[2] Institut franco-allemand de recherches de Saint-Louis (ISL), France

Despite the limited success of the Concorde, the last two decades have seen a resurgence of interest in commercial supersonic flight. In this context, the European Commission has funded the MOREandLESS project, under the Horizon 2020 plan, to assess the potential of some innovative high-speed aircraft configurations and to identify and mature the technologies needed to overcome the main obstacles to their deployment. In particular, the massive thunder-like noise produced when an aircraft breaks through the sound barrier represents one of the most persistent challenges of the supersonic regime. For this reason, a great deal of effort is devoted to the construction of various demonstrators to investigate the effects of different aircraft features on the sonic boom intensity. Through collaboration between ISL and CIRA, a series of outdoor investigation activities are and will be undertaken to provide a large amount of high-quality experimental data suitable for both sonic boom characterization and validation/refinement of current or novel analytical techniques for sonic boom estimation. The first test campaign, consisting of five free-flight tests, was carried out at the ISL (Saint-Louis, France) firing range (on 4th and 5th October 2022) on a reduced and slightly modified version of the STRATOFLY MR3 vehicle, launched with a 91 mm powder cannon at an initial Mach number of 4.7. To measure the sonic boom, ISL and CIRA deployed various types of sensors in the field. The gathered data were then post-processed to provide a sonic boom directivity diagram of the model and a comparison with the Whitham's modified linear theory predictions.

Speaker: Luigi FEDERICO
Head of the Flight Dynamic and Environmental Impact Department at the Italian Aerospace Research Centre (CIRA). Areas of expertise: aero-vibroacoustics, aeromechanics and flight mechanics.

HiSST 2024 - 191

The SCX-01 Atmospheric Re-entry Demonstrator and Thermostructural Ablative TPS Flight Experiment

G. PINAUD, J. BERTRAND, T. PICHON, S. PAMS, G. FOULON

ArianGroup SAS, France

Based on its long-lasting heritage on both rocket propulsion technologies and reentry vehicle, ArianeGroup developed since few years a novel family of 3D and versatile textile architecture. Once densified, the composite feature not only thermal and ablative properties but also thermostructural capabilities. This novel TPS concept will be tested on board the SCX-01 high speed re-entry demonstrator probe.

Speaker: Gregory PINAUD
Mr. Gregory PINAUD is currently in charge of material and instrumentation development for hypersonic and reentry vehicles, TPS architecture in the framework of R&D activities and in the EXOMARS RFM heat shield development.

HiSST 2024 - 213

The Scramjet Hypersonic Experimental Vehicle

Sara DI BENEDETTO[1], Marco MARINI[1], Pietro RONCIONI[1], Antonio VITALE[1], Paolo VERNILLO[1], G. DI LORENZO[1], Roberto SCIGLIANO[1], Salvatore CARDONE[2], Marta ALBANO[3], Roberto BERTACIN[3]

[1]Italian Aerospace Research Centre (CIRA), Italy
[2]Tecnosistem, Italy
[3]Agenzia Spaziale Italiana (ASI), Italy

The research and experimentation for hypersonic flight, aimed at creating and testing the enabling technologies for future high-speed systems, is one of the main research topics Europe has been engaging for over 20 years, mainly with the projects dedicated to hypersonic flight for passenger transport (HEXAFLY, HEXAFLY-INT, LAPCAT I&II, ATLLAS I&II, FAST20XX, STRATOFLY). In this frame the Italian Aerospace Research Centre (CIRA), by means of the national program PRORA, and the Italian Aerospace Agency (ASI) funded a project aimed at designing a propelled hypersonic demonstrator, the Scramjet Hypersonic Experimental Vehicle, and its flight experimental mission. The paper presents the baseline air-launched mission scenario that foresees the use of a carrier aircraft and a launch vehicle propelled by a booster to drive the scramjet demonstrator at the defined experimental window, and the first results and evaluations on the demonstrator configuration. A first assumption on the scale of the demonstrator has been done, and its materials layout, its avionics, airframe and the components of propulsive subsystems, including the on-board fuel tanks (hydrogen) for the scramjet engine properly sized. Massive CFD simulations along the flight trajectory have allowed the verification of the aero-propulsive balance and the definition of aerothermal loads and aerodynamic coefficients which have been used for the thermal analysis and the flight mechanics analysis and trajectory calculation, respectively.

Speaker: Marco MARINI

Dr. Marco Marini got his M.Sc. in Aeronautical Engineering and Ph.D in Theoretical and Applied Mechanics at the University of Rome "La Sapienza", respectively in 1990 and 1994. He joined CIRA in 1994, first in the Aerothermodynamics Lab. (1994-2009), then as the Head of Applications and Experimentation in Aerospace Propulsion and Reacting Flows unit (2009-2010) and Head of Combustion Unit in Propulsion Division (2011-2014). Between 2015 to 2020 he was part of the Space Integration Technology Division, and he is currently the Head of Hypersonic Vehicles unit. He has had the technical coordination and the project engineering/project management of several national and international projects in the fields of aerothermodynamics and propulsion. He is author or co-author of about 180 publications and reviewer of several international journals.

HiSST 2024 - 267

Overview of the DRACO Development Status

Jeroen VAN DEN EYNDE, Beatriz JILETE, Alex ROSENBAUM, Stijn LEMMENS

European Space Agency (ESA), Netherlands

The Destructive Re-entry Assessment Container Object (DRACO) project is an ESA mission with the aim of improving the understanding of spacecraft demise processes. DRACO consists of a fully representative satellite that will undergo a controlled destructive re-entry from Low Earth Orbit. The satellite hosts a dedicated instrument that will measure a variety of parameters on specific objects of interest within the host during the re-entry, in addition to recording visual and infrared imagery. The instrument also includes a capsule designed to survive the destructive re-entry and transmit the obtained data back to ground. The current paper provides a general status overview of the ongoing developments of the DRACO mission.

Speaker: Jeroen VAN DEN EYNDE
Dr. Van den Eynde works in the Flight Vehicles & Aerothermodynamics Engineering section at the European Space Agency.

HiSST 2024 - 273

Preliminary Conceptual Design of the Reusable Unmanned Space Vehicles using Multidisciplinary Optimization

Dabeen JEONG[1], Shinkyu JEONG[1], Jongho JUNG[2]

[1]KyungHee University, Korea
[2]Seoul National Univeristy (SNU), Korea

In this study, conceptual design of reusable unmanned space vehicle was conducted by considering multiple objective functions: minimization of weight and heat-flux at the same time. To improve these performances, MOGA (Multi-Objective Genetic Algorithm) is used. Additionally, to compute rapid calculations aerothermodynamic of reusable unmanned space vehicle during the entire flight range including re-entry stage, the modified Newtonian flow and the approximate convective-heating equation are adopted. As a baseline configuration, KSP-1 which is provided by the Korea Aerospace Research Institute (KARI) is used. The optimization result shows that the weight increases by approximately 6.45% and heat-flux decreases by about 46.07%.

Speaker: Dabeen JEONG
Dabeen Jeong is currently a M.S. student in Kyung Hee University in Korea.
His research focuses on the hypersonic aerothermodynamics.

Testing & Evaluation 1 (T&E 1)

Chairs: Prof. Hyungrok DO (SNU, Korea), Dr. Dermeval CARINHANA JR (IAS, Brazil)

HiSST 2024 - 367

Flight Qualification of the Red Kite Solid Rocket Motor

Thomas RÖHR, Frank SCHEUERPFLUG, Josef ETTL, Dietmar KAIL, Christian MILDENBERGER, Johannes RIEHMER, Christian SCHNEPF, Rainer KIRCHHARTZ

German Aerospace Center (DLR), Germany

The Red Kite© is a commercially available, serially produced solid propellant sounding rocket motor in the class of one ton of net explosive mass. It was flight qualified in November 2023 at the Andøya Space launch site in Norway after four years of development. The flight was named SOAR (Single Stage Operational Assessment of Red Kite) and was administered by DLR Mobile Rocket Base. Main objective of the flight was to collect a body of data sufficient to validate flight worthiness of the Red Kite. Secondary objective was to propel APEX-TD (Air Breathing Propulsion Experiment - Technology Demonstrator) by the DLR Institute of Aerodynamics and Flow Technology to high speed in the low atmosphere to enable in-situ research on the air flow inside a scramjet type duct. Both objectives required live streaming of data to ground because the vehicle was not equipped with a parachute recovery system. Both objectives were fully met. The vehicle reached an apogee of 71 km, a maximum speed of Mach 4.8 and impacted in the Norwegian Sea 58 km from the launch site. Key trajectory parameters are all within one standard deviation of predictions. Thus, SOAR demonstrated the capability of Red Kite and DLR MORABA supplementary systems to provide the scientific community with an easy, reliable and highly customizable flight from one of multiple launch sites around the world. The paper describes the SOAR objectives, design, execution and results including noteworthy observations from vehicle and ground based instruments.

Speaker: Thomas RÖHR
Mr. Thomas Röhr, DLR, department Mobile Rocket Base, project lead SOAR - Single Stage Operational Assessment of Red Kite, B. Eng. Aerospace Engineering (2018)

HiSST 2024 - 289

Free-flying Model Testing in the X2 Expansion Tube

Christopher M. JAMES, James J. WALLINGTON, Thien BUI, Daisy-May JOSLYN, Elsie EDWARDS, Raeph MASON, Jack MCKAY, Rose BUTLER, Flynn PEARMAN, Torri YOUNG

The University of Queensland (UQ), Australia

Free-flying model testing is a common technique used in hypersonic impulse test facilities to measure forces over scaled models of hypersonic vehicles. While this technique is widespread in low enthalpy facilities and reflected shock tunnel facilities where test times are generally of the order of milliseconds or longer, it has largely been unexamined in very high enthalpy hypersonic impulse facilities such as expansion tubes due to their much shorter test times of generally much less than a millisecond. Recent work in UQ's X2 expansion tube has aimed to change that by beginning free-flying model testing and validation in the facility. This paper will summarise current free-flying model testing in UQ's X2 facility while also discussing new supporting techniques which are being developed, such as an off-axis parabolic schlieren system for model illumination and a pneumatically operated model release system.

Speaker: Christopher M. JAMES
Dr Chris James is a UQ Amplify Senior Lecturer at the University of Queensland where he runs UQ's X2 expansion tube facility - an impulse wind tunnel for the simulation of planetary entry and high enthalpy, high-speed flight.

HiSST 2024 - 365

Design and Objectives of the Air-breathing Propulsion Experiment Technology Demonstrator (APEX-TD)

Johannes RIEHMER, Florian KLINGENBERG, Thomas RÖHR, Christian ZUBER, Christian SCHNEPF, Ali GÜLHAN

German Aerospace Center (DLR), Germany

Ramjets and Scramjets have the potential to be the next generation alternatives for high-speed flight with air-breathing propulsion system and access-to-space. APEX-TD is a DLR low-cost flight experiment designed to investigate essential technologies for afore mentioned propulsion concepts and provide real flight data for verification of numerical simulations and experiment data. The flight was launched on top of a single-stage Red Kite sounding rocket during its qualification flight on November 13, 2023 in Andøya, Norway.
The main characteristic of the experiment is a supersonic axial-symmetric inlet with internal flow path and an active starting mechanism for a design Mach number of 5. During the flight a maximal Mach number of 4.8 was reached. As key technologies for scramjet combustion 3D printed looped strut injectors with nitrogen injection were tested. Further features were ceramic structures integrated in vehicle components with high aerothermal loads and a dedicated instrumentation of the external and internal flow path. This paper gives an overview of the vehicle design concept, experimental set-up and configuration as well as scientific objectives of the APEX-TD experiment in general. It also provides results of first analysis of the flight trajectory and scientific data collected during the flight.

Speaker: Johannes RIEHMER
Johannes RIEHMER studied of Aerospace Engineering at University Stuttgart. He has been at German Aerospace Center for Diploma Thesis at the Supersonic- and Hypersonic Technologies Department since 2007.

HiSST 2024 - 326

The Current Status of Free-Flight Testing of a Scramjet-Integrated Hypersonic Cruising Vehicle Model in the HIEST Free-Piston Shock Tunnel

Hideyuki TANNO, Shuto YATSUYANAGI, Kouichiro TANI, Sadatake TOMIOKA

Japan Aerospace Exploration Agency (JAXA), Japan

Scramjet vehicles require an assessment of overall aerodynamic stability and scramjet operational characteristics due to strong coupling between fuselage attitude and scramjet performance. In particular, the pitching characteristics, which directly affect the scramjet combustor inlet temperature and pressure, are crucial for scramjet combustion. Shock tunnels, capable of generating hypersonic test flows, have been used extensively for scramjet tests particularly flight Mach number 8 or higher condition. Despite their short test durations, these tunnels offer clean test flows without contamination from combustion products and allow testing under high Reynolds number conditions similar to realflight condition, due to their high stagnation pressure. JAXA conducted series of tests in the free-piston shock tunnel HIEST, using a 1.1m long scramjet fully integrated model MoDKI (Model of Demonstrator Kakuda Initiative) to measure three-components aerodynamic coefficients (drag, lift, pitching moment). The MoDKI tests assessed the model's overall aerodynamic characteristics, including longitudinal stability of the model, and evaluated the performance of a newly developed, model-onboard fuel injection system. However, due to excessive onboarded equipment in the model relative to its internal volume, there were challenges with fuel supply piping and valve arrangement, leading to insufficient fuel supply pressure

and difficulties in combustion testing. In response, JAXA designed and manufactured a new scramjet-airframe integrated model NAMaSU (New Airframe integrated Model with a Scramjet Unit), with a wider width and increased internal volume based on insights from the MoDKI tests and conducted free-flight tests in HIEST. This report describes a preliminary report of the combustion test of the NAMaSU with gaseous hydrogen under Mach 11 equivalent flight conditions. Tests were conducted by varying the equivalent ratio by changing the injection pressure, and comparative tests of with and without combustion were conducted using air and pure nitrogen as test gases in order to extract the effect of hydrogen gas combustion. A large pressure increase due to hydrogen combustion was observed in the combustor, but no thrust was generated to counteract the drag force.

Speaker: Shuto YATSUYANAGI

He is a researcher working at JAXA Kakuda Space Center and has a PhD in Information Science. His research interests include numerical simulations of aerodynamic heating and boundary layer transitions in high enthalpy hypersonic flows.

HiSST 2024 - 354

Active and Passive Vibration Control Technology for Tri-sonic Wind Tunnel Models

Huanhuan YAN, Wenbin NI, Junfei WU, Xiaojun PAN, Jian ZHOU, Wanfang YAN, Sen LIU, Tiejin WANG, Jiang ZHANG

China Academy of Aerospace Aerodynamics (CAAA), China

In subsonic and supersonic wind tunnel tests, the commonly used tail brace is a typical concentrated mass cantilever beam structure. In transonic and supersonic flow, the airflow and model support system sometimes undergo severe coupling vibration, and the alternating vibration of the model can have a very adverse impact on the accuracy of the balance measurement system and the reliability and lifespan of the support system. Under a specific high angle of attack, the experiment generates rapid divergent vibrations with obvious resonance characteristics, which cannot achieve the completion of data collection of the angle of attack envelope, and can seriously damage the safety of the test structure and balance system. Passive vibration suppression using non Newtonian materials and tungsten steel support rods, and active vibration suppression using piezoelectric ceramics to achieve the best vibration suppression effect. Due to the advantages of high energy density and rapid response of piezoelectric ceramic materials, the use of piezoelectric ceramic actuators as active vibration suppression technology for wind tunnels has become a research hotspot. Based on the principle of variable stiffness active vibration suppression, an active and passive vibration suppression system was designed in the wind tunnel using stacked piezoelectric ceramic actuators. The main purpose of the system is to solve the serious vibration problems that occur in the model during transonic testing. Based on the analysis of key techniques in model vibration, the design optimization of the layout of the vibration suppressor was achieved. The feasibility of this design method and the performance of the entire vibration suppression system were verified through ground and wind tunnel tests. The test results showed that the vibration suppression system can suppress the impact vibration of the model's supersonic switching vehicle and the vibration caused by aerodynamic structure coupling, and effectively improve the available attack angle of the test, providing a reliable testing technology for the model's supersonic test.

Speaker: YAN Huanhuan

Active and passive vibration control technology for tri-sonic wind tunnel models

Chairs: Dr. Roberto GARDI (CIRA, Italy), Mr. Ron SHARABANI (IAI, Israel)

HiSST 2024 - 026

Development of a Dual-Layer Ablator for Spacecraft Heat Shield Applications

Rajesh Kumar CHINNARAJ, Young Chan KIM, Seong Man CHOI

Jeonbuk National University (JBNU), Korea

For spacecraft heat shield applications, we developed a dual-layer carbon-phenolic/silica phenolic ablator. The development of this dual-layer ablator began with testing a carbon-phenolic material with two different lamination angles of 0° and 30°, using a high-velocity oxygen fuel (HVOF) material ablation test facility. Based on HVOF results, the 30° carbon-phenolic material (used as a recession layer) is selected as the base for the dual-layer ablator. The 30° carbon-phenolic material was augmented with a silica-phenolic material (used as an insulating layer) and tested in a 0.4 MW supersonic arc-jet plasma wind tunnel. In plasma wind tunnel tests, dual-layer ablator specimens with varying thicknesses of carbon-phenolic layers and different surface shapes (flat-faced and hemispherical-faced) were tested. The plasma wind tunnel tests showed the specimen silica-phenolic recession layer internal temperatures were well below the set design limit of 453.15 K (180 °C). The surface temperatures of the hemispherical-faced specimens measured around 3000 K, approximately 350 K higher than those of the flat-faced specimens, leading to elevated internal temperatures. Under identical test conditions, hemispherical-faced specimens exhibited approximately 1.4 times greater recession and mass loss compared to the flat-faced specimens.

Speaker: Rajesh Kumar CHINNARAJ
Rajesh is a Postdoctoral Researcher at Jeonbuk National University, South Korea. During his graduate studies, he extensively worked with spacecraft thermal protection system material ground testing facilities, including a supersonic arc-jet plasma wind tunnel. Specializing in atmospheric entry process and spacecraft heat shield material testing, he now focuses on the development of both ballistic and winged spacecraft.

HiSST 2024 - 317

Exploratory Design and Evaluation of Alumina-Based Oxide/Oxide Ceramic Matrix Composite for Integrated Thermal Protection System Application

Vinh Tung LE, Abhendra K SINGH

Baylor University, USA

In this study, an integrated thermal protection system (TPS) based on alumina-based oxide/oxide ceramic matrix composite is explored. The structure is based on corrugated core sandwich concept and is fabricated using prepregs that constitute NextelTM720 fiber and alumina matrix. Fabricated sandwich panels are tested for survivability, nature and extent of erosion, and overall thermal resilience by being subjected to inductively generated air plasma in near-vacuum environment that simulate high altitude hypersonic flight condition. In addition, one-sided thermal shock and hold tests are performed using a furnace at 1550°C to evaluate pure thermal effects on the structure. Both the high temperature tests are performed for durations up to 30 minutes. The structural integrity of the sandwich structure is evaluated at room temperature using bend test, with strain measurements taken by digital image correlation. The thermal and structural test results combined provide useful information regarding the utility of the adopted design as well as the success of the fabrication method. The study also exposes areas of vulnerability, with potential for improvement, in order to arrive at a robust oxide-based sandwich composite for use as thermal protection system in hypersonic vehicles.

Speaker: Abhendra K SINGH

Dr. Abhendra Singh is an Assistant Professor in Mechanical Engineering at Baylor University in Waco, TX, USA. His research focus is on ceramic matrix composites both for gas turbine and hypersonic applications. His research collaboration involves both industry and federal labs in the US.

HiSST 2024 - 134

Preliminary Thermal Assessment of an Air-launched Propelled Hypersonic Experimental Vehicle

Roberto SCIGLIANO[1], Marco MARINI[1], Sara DI BENEDETTO[1], Marta ALBANO[2], Giuliano RANUZZI[2]

[1]Italian Aerospace Research Centre (CIRA), Italy
[2]Agenzia Spaziale Italiana (ASI), Italy

In the last decade, international community has shown an increasing interest in civil high-speed aviation. In particular, several studies have been carried out to assess the technical possibility of hypersonic civil flights paying attention at technical, environmental and economic viability in combination with human factors, social acceptance, implementation and operational aspects. In the past years, some innovative high-speed aircraft configurations have been proposed as results of dedicated multi-disciplinary and highly integrated design concept where aerothermodynamic, structural and propulsive issues are evaluated together in the frame of European Commission-supported research projects such as: LAPCAT I/II [1-3], ATLLAS I/II [4], HIKARI, HEXAFLY [5], HEXAFLY-International [6], STRATOFLY [7, 8, 9, 10].

In this context, starting from an in-depth investigation of the status of past and on-going activities, CIRA has launched a national project funded by PRO.R.A. (Aerospace Research Program), aiming at designing, manufacturing and flight-testing a propelled hypersonic demonstrator, namely the Scramjet Hypersonic Experimental Vehicle (SHEV) [11]. The Italian Space Agency (ASI) is also funding the activities for a three-year period. This paper focuses the attention on the preliminary thermal assessment of the experimental flight vehicle mainly from the structure and material point of view.

Speaker: Roberto SCIGLIANO

Dr. Roberto SCIGLIANO is a Senior Researcher at Structures and Materials Department in Italian Aerospace Research Center – CIRA scpa.

HiSST 2024 - 229

Optimization and Characterization of CARBOTEX®-Si, a CMC for Hypersonic Applications

Félix BAN, Tobias SCHNEIDER, François FALEMPIN, Stephan SCHMIDT-WIMMER

MBDA, France

Ceramic Matrix Composites (CMCs) are highly studied and used for the range of supersonic and hypersonic applications over the world. With the collaboration of ArianeGroup Gmbh (AGG), MBDA has been developing such materials for its vehicles. Since the early 2000s MBDA, and its customer DGA, has selected the CARBOTEX® as the CMC that can be the structural material constituting the scramjets. This paper gives a short presentation on the CARBOTEX® and its variants (C/C and C/C-Si) and focuses on the studies that have been led over the last five years in the frame of manufacturing process optimization, material design understanding and thermo-mechanical characterization.

Speaker: Félix BAN

Félix Jean Christian BAN 2017 - Master of Science in Mechanical Engineering from "Arts et Métiers ParisTech" Engineering School, in France 2018 - Master of Science in Aerospace Engineering from "University of Michigan", Ann Arbor, MI, USA Since 2018 - Design Authority in Hypersonic Programs at MBDA France

HiSST 2024 - 215

Deformation Measurement of Stainless Steel in High-temperature Environments using DIC for Thermal Protection System

Nam Seo GOO, Xiongjie CHE

Konkuk University, Korea

A heat shield called the thermal protection system (TPS) is an important structure in high-speed vehicle as it protects the vehicle from aerodynamic heating. In order to study the TPS, it is particularly important to measure the deformation of structures in high temperature environments. This study presents an improved method for high-temperature measurement using the digital image correlation (DIC) technique and infrared heater, with a focus on the effects of speckle patterns and mitigation of heat haze effects. The effect of speckle pattern on the DIC measurement has been studied well at room temperature, but high-temperature measurement studies did not report such effects so far. And we also found that the commonly used methods to reduce the heat haze effect could produce incorrect results. So, we studied how to determine the proper size of the speckle pattern under a high-temperature environment. And then we invented the reduction method of the heat haze effect. Finally, we mitigated image saturation using a short-wavelength bandpass filter with blue light illumination to avoid the blackbody radiation from the heated structure, a standard procedure for high-temperature DIC deformation measurement. As proof of our developed experimental method, the deformation of stainless steel 304 specimens was measured from 25 °C to 800 °C successfully, which means this method can be applied to the research and development of thermal protection systems in the aerospace field.

Speaker: Nam Seo GOO

Thermal and Energy Management Systems 1 (TEM 1)

Chairs: Mr. Francois FALEMPIN (MBDA, France), Prof. Hyung Ju LEE (PKNU, Korea)

HiSST 2024 - 192

Performance of a Transpiration-Cooled Sharp Leading Edge for Hypersonic Flight

Raghul RAVICHANDRAN, Luke DOHERTY, Matthew MCGILVRAY

University of Oxford, UK

This paper presents the modelling and feasibility assessment of using transpiration cooling in the context of active thermal protection systems for hypersonic sharp leading edges. Heat flux reduction effects of transpiration and fim cooling are modelled using semi-empirical correlations from literature, which are corroborated and improved on using high fidelity numerical work. A previously developed numerical tool, PIRATE, is used for rapid calculations for temperature of the vehicle substructure. The model was constrained by assessing coolant volumetric requirements, and employing moderate mass injection parameters, Bh, due to boundary layer blowoff and pressure drag penalties associated with large mass fluxes. The results show that transpiration cooling may be a viable thermal protection system for long duration trajectories at moderate altitudes and Mach numbers, where ablative and passive systems are not possible. For trajectory points typical of a airbreathing ascent corridor ($M_\infty = 7$, alt. = 35 km), leading edge radii (RLE) above 20 mm do not require active thermal protection if used with high performance materials such as reinforced carbon-carbon. For smaller radii with transpiration cooling, Helium coolant has a lower mass penalty than Nitrogen coolant, however Helium is associated with a higher volume penalty and a higher minimum operating temperature due to a lower threshold for boundary layer blowoff.

Speaker: Raghul RAVICHANDRAN
Raghul is a DPhil student at the University of Oxford, conducting experiments and numerical simulations of transpiration cooling for sharp leading edges.

HiSST 2024 - 178

Experimental Study on Thermal Decomposition Characteristics of exo-THDCPD

Seung Mook PARK, Seung Hyeon LEE, Hyung Ju LEE

Pukyong National University (PKNU), Korea

When hydrocarbon aviation fuel is heated above its critical point inside a regenerative cooling channel, the fuel is decomposed into hydrogen and various low molecular-weight hydrocarbons, which affects the performance of active regenerative cooling systems. Therefore, this study investigates the pyrolysis of exo-THDCPD ($C_{10}H_{16}$, exo-tetrahydrodicyclopentadiene), the major component of JP-10 aviation fuel experimentally. In order to understand the thermal decomposition characteristics of exo-THDCPD within a regenerative cooling channel, a batch reactor with a fluidized sand bath heater was used to expose the fuel under supercritical conditions (4 MPa, 540-630 K) to have the conversion rate of 3-76%. The constituents of the pyrolysis products were identified by GC-MS, GC-FID and GC-TCD systems, which have revealed that hydrogen, methane, ethylene, ethane, propylene, propane, and butane are found to be the major gaseous products. In the liquid products, on the other hand, cyclopentane, cyclopentene, cyclopentadiene, cycloheptadiene, benzene, and toluene are dominant. Furthermore, a brief analysis on the thermal decomposition mechanism was carried out based on the experimentally obtained data.

Speaker: Seung Mook PARK
Seung Mook Park is currently a M.S. student in Department of Mechanical Engineering, Pukyong National University. His research focuses on hypersonic aircraft.

HiSST 2024 - 212

Transpiration Cooled Fin Flight Experiment FinEx II on HIFLIER1

Giuseppe D. DI MARTINO[1], Jonas PEICHL[1], Fabian HUFGARD[2], Christian DÜRNHOFER[2], Stefan LÖHLE[2], Johannes GÖSER[3]

[1]DLR Institute of Structures and Design, Germany
[2]High Enthalpy Flow Diagnostics Group (HEFDiG), Germany
[3]DLR Mobile Rocket Base, Germany

The flight in hypersonic conditions implies important challenges for the vehicle development concerning in first place the thermal protection of the external structures, especially in the presence of sharp edges, where the high heat loads generated by the strong attached shock waves become even more critical. For these applications, a new variant of the C/C-SiC material with defined porosity level has been developed in the past years in order to combine the high-temperature resistance of the CMC material with the transpiration cooling technology. In the present paper, the activities for the flight testing of such technology applied to sharp leading-edge fins in hypersonic conditions is presented. For this purpose, in the framework of the HIFLIER flight research experiment, an experimental module of the sounding rocket was designed and constructed, housing four fins with leading edge made of the new porous CMC material and connected to a nitrogen gas supply system for the transpiration cooling application.

Speaker: Giuseppe D. DI MARTINO
Giuseppe Di Martino is a research scientist at the Institute of Structure and Design of the DLR. He comes from Napoli, where he got his master in Aerospace Engineering at University "Federico II" in 2015. Also at University "Federico II" in Napoli, he got his PhD in 2018 with a dissertation on propulsion systems and Ultra-High Temperature Ceramic Matrix Composite materials for aerospace application. At the Institute of Structure and Design he works mainly on the design, manufacturing and integration of structures and systems for thermal protection in hypersonic flight conditions.

HiSST 2024 - 217

Inflatable Heat Shields Solutions for Hypersonic Re-entry Applications: the European Commission EFESTO-2 Project

Giuseppe GUIDOTTI[1], Federico TOSO[1], Alessandro PRINCI[1], Jaime BRICENO-GUTIERREZ[1], Giuseppe GOVERNALE[2], Nicole VIOLA[2], Ingrid DIETLEIN[3], S. Callsen[3], K. Bergmann[3], Junnai ZHAI[3], Thomas GAWEHN[3], Roberto GARDI[4], Barbara TISEO[4], Ysolde PREVEREAUD[5], Yann DAUVOIS[5], C. Julien[5], Giovanni GAMBACCIANI[6], Giada DAMMACCO[6], L.Garcia-Basabe[7]

[1]Deimos Space S.L.U, Italy
[2]Politecnico di Torino, Italy
[3]German Aerospace Center (DLR), Germany
[4]Centro Italiano Ricerche Aerospaziali (CIRA), Italy
[5]Office National d'Etudes et de Recherches Aerospatiales (ONERA), France
[6]Pangaia Grado Zero SRL (PGZ), Italy
[7]Deimos Engenharia, Portugal

Inflatable Heat Shields (IHS) are attracting an increased interest in the field of some hypersonic applications as the one of re-entry.
In Europe the "ram's head" project EFESTO, funded by the European Commission through the Horizon 2020 program and run form 2109 and 2021, allowed the scientific community to carry out an early exploration of the potential use of this technology to recover space systems re-entering from LEO (e.g.: launch vehicle stages, satellites, space station elements). ([1] to [3])

In the track-lay of EFESTO, the project EFESTO-2, funded by the EU program Horizon Europe, aims to further increase the European know-how in the field of Inflatable Heat Shields (HIS) and seeks to improve further the Technology Readiness Level (TRL) of IHS. ([4] to [6])

The EFESTO-2 project is built on four pillars: (1) consolidation of use-case applicability through a business case analysis for a meaningful space application; (2) extension of investigation spectrum of the father project EFESTO; (3) increase of confidence-level and robustness of tools/models; (4) consolidation of European leadership among the scientific and industrial community in this specific field.

This paper presents the project's work and achievements up to completion going across its main work items of execution of a mission and system design loop for a reference application in a baseline use-case scenario; implementation of a sound testing effort covering the key aspects of structural characterization of the inflatable structure as well as deformable shape investigation from the aerodynamic standpoint including stability; verification and improvement of numerical models both at structure (FEM) and aero-shape (CFD) levels; identification of the roadmap and near-future effort toward maturation of the IHS technology for a systematic use on real re-entry missions.

This project has received funding from the European Union's Horizon Europe research and innovation program under grant agreement No 1010811041.

Speaker: Federico TOSO

After the Polytechnic University of Turin, and the Doctorate at the University of Strathclyde, I joined Deimos Space where I lead the optimisation developments of the Atmospheric Flight centre, focusing on present and future launch vehicles.

SHORT ABSTRACTS

APRIL 16
TUESDAY

ORAL PRESENTATION

High-Speed Aerodynamics and Aerothermodynamics 3 (HSA3)

Chairs: Prof. Eunji JUN (KAIST, Korea), Prof. Alexandre MARTIN (University of Kentucky, USA)

HiSST 2024 - 137

HIFiRE-5 Testing in the Oxford High Density Tunnel

Samuel BROADHURST, Luke DOHERTY, Matthew MCGILVRAY, William IVISON, Chris HAMBIDGE

University of Oxford, UK

Boundary layer transition leads to a significant increase in viscous forces and heat transfer at hypersonic speeds due to the high energies involved. In absence of a complete understanding of this phenomenon, hypersonic vehicle design is impaired. In particular, transition on certain geometries is affected by cross flow waves and vortices which must be further understood. The Hypersonic International Flight Research Experimentation (HIFiRE) program aims to measure transition on a 3-D geometry with partial rotational symmetry. The 5th flight vehicle of the programme (HIFiRE-5) is a 2:1 elliptical cone which has received flight tests, and scale models have undergone ground testing. This work is part of a project aiming to measure transition on a 38.1\% scale model of the HIFiRE-5 geometry in the Oxford T6 Stalker tunnel at high enthalpies. This paper presents preliminary testing in the Oxford High Density Tunnel. Transition was observed on the model via IR thermography; thin film temperature gauges; pressure sensors; and schlieren capture; with the aim of validating the instrumentation and processing ahead of future testing in T6.

Speaker: Samuel BROADHURST

Final year undergraduate student at the University of Oxford; studying towards and MEng Engineering Science degree, specializing in aerospace and mechanical engineering. Presenting research analysed in his summer internship in the hypersonics group at the oxford thermofluids institute in 2023.

HiSST 2024 - 179

Investigation on the Linear Stationary Crossflow Stability Characteristics of Hypersonic Boundary Layer with Expansion Corner

Peisen LU, Youcheng XI, Song FU

Tsinghua University, China

The expansion corner is a typical kind of structure on swept wings of hypersonic vehicles, which has a great effect on crossflow instabilities. This work aims to investigate the actual effect of the expansion corner on linear instabilities in practical three-dimensional hypersonic flow regimes. Hypersonic swept flows over a designed wing model of real vehicles are studied. The flow is calculated at a free-stream Mach number of 6 with the adiabatic wall condition. The model consists of a blunt cone, after which comes an expansion corner along with a flat plate. The corresponding laminar flow computations with different swept angles have been carried out using in-house shock-fitting procedures in order to ensure the quality of the base flow. Linear stability theory (LST) has been incorporated in investigating the effects of expansion corner on stationary crossflow instabilities. The most unstable mode which dominates the instability behaviour is calculated at interested streamwise locations. Both growth rates curves and neutral curves are calculated to illuminate the instabilities in this regime.

Speaker: Peisen LU
Peisen Lu is a Ph.D. student at the School of Aerospace Engineering, Tsinghua University. His research focus is primarily on three-dimensional hypersonic boundary layer stability and transition.

HiSST 2024 - 197

Frequency Modulation Analysis in Innovate Supersonic Cavity Flow

Ting Tsung CHANG, Konstantinos KONTIS

University of Glasgow, UK

Modulation characteristics of the cavity still inspires people to study through variety of mathematic approaches. The primary purpose here is to apply not only conventional fast Fourier transform but continuous wavelet transform to study the spectrum of different cavity flow configurations experimentally. Via modulation analysis, we find that suggested modulation parameter, normally 0.25, in theoretical model is not always constant. Since the shear layer impingement on the trailing-edge is the dominant source driving the aeroacoustic mechanism, the angled ramp significantly alters its development and level of the pressure tone drops dramatically. An innovate passive control method with sub-cavity introduced recently is studied in this paper as well. The sub-cavity applied on aft wall, however, considerably amplifies pressure tones inside the sub-cavity and induces extra modes by fluidic resonance. Moreover, frequency spectrum of AM of individual Rossiter mode indicates the interaction between each mode.

Speaker: Ting Tsung CHANG
Former aerospace engineer in Taiwan for 4 years, now studying in UofG as a PhD in aerospace science.

HiSST 2024 - 249

Aerodynamics of the Reusable Launch Vehicle Supersonic Retropropulsion System

Jesslyn Wei Yan ONG, Yujoo KANG, Jaemyung AHN, Sang LEE

Korea Advance Institute of Science and Technology (KAIST), Korea

Reusable Launch Vehicle (RLV) has validated the vertical takeoff and vertical landing reusable rocket concept through the implementation of a robust vehicle design tailored to the well-structured mission profile executed in distinct phases, varying in altitude and travel speed. This study performs an in-depth exploration of the flowfield attributes and comprehensive aerothermal analysis of the vehicle and the surrounding atmosphere. Additionally, the study of angle of attack is of paramount significance, especially during the flip manoeuvre, wherein the vehicle encounters dynamic changes in this parameter. The employment of the Reynolds Averaged Navier-Stokes (RANS) solver in conjunction with the ShearStress Transport (SST) k-ω model within SU2 was instrumental in conducting these analyses. The findings reveal that as the vehicle progresses to lower speeds and altitudes, the manifestation of shock and plume formation becomes less pronounced, consequently diminishing the associated aerothermal effects.

Speaker: Jesslyn Wei Yan ONG
Affiliation and Position: M.S. candidate, Korea Advance Institute of Science and Technology
Education and Degree: B.S. in Aerospace Engineering – University of the West of England, 2023

HiSST 2024 - 226

Design of Pulsed Magnetic Circuit with Pulse Forming Network for Experimental Study of Magnetohydrodynamic Aerobraking

Takeaki MURAMATSU[1], Yosuke KUROSAKA[1], Kohei SHIMAMURA[1], Akira KAKAMI[1], Hiroshi KATSURAYAMA[2]

[1]Tokyo Metropolitan University (TMU), Japan
[2]Tottori University, Japan

In this paper, a magnetic circuit is designed for the study of MHD aerobraking using a pulsed magnetic field in a hypersonic wind tunnel (Expansion tube). The magnetic circuit is composed of a magnetic field generating coil, a Pulse Forming Network (PFN) as a power source, and a drive circuit centered on IGBT. A magnetic field generating coil with a diameter of 12 mm was fabricated, confirming a magnetic field density of 1.3 T on the specimen surface. Subsequent wind tunnel tests, utilizing the fabricated magnetic circuit, resulted in the acquisition of self-luminous images. A comparison of these images revealed a difference of approximately 15% in the self-luminous region. These results suggest that the application of pulse magnetic fields to the test airflow confirmed changes in the shock wave layer.

Speaker: Takeaki MURAMATSU
Takeaki Muramatsu was received the B.E. degrees in Aeronautics and Astronautics from the Tokyo Metropolitan University, Tokyo, Japan, in 2023. He is now a master course student. His research interest includes shock wave and Detonation.

HiSST 2024 - 265

Hypersonic Crossflow-induced Breakdown and Transition Correlation Based on Secondary instability Modes on a Swept Flat Plate

Gen LI, Caihong SU

Tianjin University, China

Hypersonic crossflow transition was investigated for a Mach 6 flow over a swept plate with a swept angle of 45deg by solving the compressible three-dimensional Navier-Stokes equations. In order to obtain the transition process, the nonlinear evolution of a stationary crossflow vortex was first simulated. After it saturated, broad-spectrum wall perturbations were imposed through a slot to trigger transition. The results showed that both the Type-I and -III secondary modes are excited during the transition, which grow exponentially and independently due to secondary instability. Overall, the Type-I mode achieves the largest amplitude and dominates the transition. Furthermore, the amplitude of the most amplified secondary instability mode based on bi-global analysis is used to correlate the transition locations for DNS cases with four different wall perturbation amplitudes, spanning across four orders of magnitude.It was demonstrated that the amplitude criterion based on secondary instability well correlates the transition locations for the DNS cases, which validates the amplitude criterion based on secondary instability for crossflow transition prediction.

Speaker: Caihong SU
Prof. Caihong Su, head of the High-Speed Aerodynamics Lab, School of mechanical engineering at Tianjin University, specializes in high-speed boundary-layer instability and transition, flow control and related issues.

Chairs: Prof. Rho Shin MYONG (GNU, Korea), Prof. Christian MUNDT (UniBw M, Germany)

HiSST 2024 - 188

A Study on the Aerodynamics and Aerothermodynamics of a Supersonic Reefed Parachute

Weijie XU, Yi LI

Northwestern Polytechnical University (NWPU), China

Parachute, due to its low mass and high aerodynamic drag, is an important deceleration device in the fields of Earth's atmospheric re-entry deceleration, planetary entry, and deep space exploration. Supersonic parachutes, represented by disk-gap-band (DGB) parachutes, have gradually reached their maximum system mass and deployment velocity limits. To address this issue, researchers have designed a reefing system on the DGB parachute just like on the subsonic parachute, to reduce the inflation load to get a higher system mass and entry velocity.

This paper establishes a reefed DGB parachute model based on the parachute of Mars Science Laboratory mission, and studies the aerodynamic and aerothermal characteristics of the supersonic reefed parachutes. This paper uses fluid-structure-interaction (FSI) technology to study the canopy inflation processes of reefed and disreefed parachute, and clarifies the aerodynamic characteristics such as drag and stability. Several typical states during the inflation process include initial state, mid-inflation state and canopy stable state are selected to establish corresponding parachute system models by computer-aided-design (CAD). The aerothermal characteristics of canopy macroscopic and microscopic structures are studied. Finally, the reefing design method suitable for the supersonic DGB parachute is obtained. All the works are to support deep space exploration such as Mars exploration.

Speaker: Weijie XU

Weijie Xu is a PhD student at the School of Astronautics, Northwestern Polytechnical University, China, since 2020. He received his Bachelor degree in 2017 and Master degree in 2020. His research is mainly on the flight vehicle design and aerodynamics.

HiSST 2024 - 240

Numerical Investigation of Magnetic Heat Flux and Electron Manipulation System for Hypersonic Vehicles

Thomas J. GREENSLADE, Arunkumar CHINNAPPAN, Minkwan KIM

University of Southampton (UoS), UK

The renewed interest in hypersonic flights has brought fresh attention to the physical challenges in reusable thermal protection systems. The need to enhance the reliability of hypersonic and re-entry vehicles has sharply focused on the limitations of our current comprehension of thermos-chemical non-equilibrium flows and our restricted predictive capabilities. This paper presents the work carried out by the University of Southampton and our consortium partners within the MEESST collaboration. This project is currently involved in both numerical and experimental research to develop magnetic shielding techniques for atmospheric re-entry vehicles. These techniques aim to offer additional approaches for mitigating heat flux. Here, we present the results of multi-physics simulations conducted with the University of Southampton's HANSA toolkit, along with comparisons, both experimental and numerical, produced by our consortium partners. These encompass simulations of multiple capsules undergoing atmospheric re-entry and simulations of ground-based experimental campaigns.

We give particular attention to the effects of thermo-chemical non-equilibrium and MHD modeling. We illustrate the impacts of various mathematical models on the results obtained, with a strong emphasis on mission-critical parameters like surface heat fluxes and electron densities. We also present conclusions regarding the implications of these results on magnetic shielding designs. We demonstrate differences in thermal relaxation rates in terms of their effects on impinging heat fluxes. We then investigate the influence of these rate variations on magnetic heat flux mitigation techniques. Lastly, we offer an overview of current knowledge gaps in areas crucial to MEESST and lay out plans for future simulations and experiments, both within the MEESST project and beyond.

Speaker: Minkwan KIM
Dr Minkwan Kim (MK), Associate Professor in Astronautics is an expert in thermo-chemical non-equilibrium flows and plasma dynamics. Dr Kim has been PI and Co-I on over £3M worth of projects; is on the UK Space Agency space exploration advisory committee Board (SEAC) and the AIAA Plasma dynamics and Laser technical committee.

HiSST 2024 - 129

Experimental Visualization of Hypersonic Boundary Layer Transition

Duk-Min KIM, Hyoung Jin LEE

Inha University, Korea

Hypersonic aircraft design faces a significant challenge in the form of aerodynamic heating, exemplified by aircraft like X-51, HGB, and HTV2. Surface temperatures during hypersonic flight can reach extreme levels, up to 2200K, causing severe damage. Aerodynamic heating impacts the aircraft surface and varies with the boundary layer's state. Laminar boundary layers exhibit low heat transfer rates, resulting in minimal damage. However, turbulence drastically increases heat transfer rates, leading to thermal damage. The transition region from laminar to turbulent flow experiences the highest heat transfer rates. To mitigate this, techniques are employed, such as heat shields, surface cooling jets, and porous surfaces, to maintain a laminar boundary layer. The Mack Second Mode instability is a primary trigger for laminar-to-turbulent transition. Delaying this instability through porous surfaces reduces turbulence-related damage. However, applying porous materials across the entire surface increases weight, making selective application crucial. This study aims to visualize the Mack Second Mode and measure surface heat transfer rates to diagnose boundary layer transition.

Speaker: Duk-Min KIM
Mr. Duk-Min KIM is a Ph.D. candidate in the Jet Propulsion Laboratory at Inha University. My research focuses on the hypersonic aerothermodynamics.

HiSST 2024 - 127

Aerodynamic and Propulsive Assessment of an Experimental Hypersonic Scramjet System

Pietro RONCIONI[1], Oreste RUSSO[1], Francesco CASCONE[1], Marco MARINI[1], Sara DI BENEDETTO[1], Marta ALBANO[2], Roberto BERTACIN[2]

[1]Italian Aerospace Research Centre (CIRA), Italy
[2]Agenzia Spaziale Italiana (ASI), Italy

The present paper deals with the aerodynamic and propulsive characterization of a Hypersonic Scramjet System, composed by Launch Vehicle (LV) and Flight Demonstrator (SHEV), as part of a research project on experimentation for hypersonic flight and enabling technologies for future high-speed transportation systems, co-funded by CIRA and ASI. The winged rocket-based launch vehicle is conceived to bring at target altitude and velocity the scramjet hypersonic experimental vehicle (SHEV) posing the challenge of creating, at national level, an aircraft capable of supporting a levelled hypersonic flight thanks to the introduction of a scramjet propulsion system.

Speaker: Pietro RONCIONI

Dr. Pietro Roncioni got his Degree in Aeronautical Engineering in 1994 and the Ph.D. in Thermo-Mechanical Engineering Systems in 2000, both at University of Naples "Federico II". He has been employed at CIRA since 2001 working in the fields of Aerodynamics, Aerothermodynamics, Propulsion and Combustion. He has been involved in several research projects, both national and international (USV, HYPROB, VEGA, VEGA-C, FLPP-IXV, LAPCAT-II, STRATOFLY).

HiSST 2024 - 230

Investigation of Aerodynamic Coefficient and Compressibility Effect of AGARD-B Model Based on Wind Tunnel Experiment and CFD Simulation

Hung-Yen CHOU, Hsien-Hao TENG

National Chung-Shan Institute of Science and Technology (NCSIST), R.O.C.

The aerodynamic coefficient of AGARD-B model is measured in wind tunnel. According to the definition, the total drag is the sum of fore body drag and base drag. To calculate the fore body drag precisely, the base pressure data must be measured accurately. In this test, the base drag was found apparently much higher than other tests performed by Arnold Engineering Development Center (AEDC) in USA and Advisory Group for Aerospace Research and Development (AGARD) in Europe. To correct this error, the static pressure data at the model support position must be measured by static-pressure probe. After re-calculation, both the base drag and fore body drag have been in the region offered from AGARD publications. Furthermore, the coefficient is validated to the result from CFD Simulation, and the data is within the tolerance range. The numerical simulations were performed using ANSYS Fluent 2023, and a structured mesh with near wall treatment and the κ-ω SST turbulence models. Proceed to the next step, the flow topologies over the AGARD-B model at Mach 0.80, 0.95, 1.05, and 1.2. According to the experiment data and flow-field simulation, the vortex bursting occurs along with the decrease of lift. When vortex bursting happens, there's a recovery shock that exists between the primary and secondary vortex, and a lack of shock is observed between the wing and vortex. As the angle of attack or Mach number increases, the vortex bursting location would be different, which need to be replicated in wind tunnel using the additional equipment if possible.

Speaker: Hung-Yen CHOU

Hung-Yen Chou is a Wind tunnel test engineer in the Aeronautical Systems Research Division, National Chung-Shan Institute of Science and Technology.

HiSST 2024 - 106

A 3D Parallel Lagrangian Finite Volume Scheme for Ideal MHD Equations

Xiao XU, Hongbo LU, Jian LIN, Feng JI, Nong CHEN

China Academy of Aerospace Aerodynamics (CAAA), China

MHD is widely applied in the area of hypersonic flow control, fusion energy, celestial physics and so on. This paper presents a 3D parallel Lagrangian scheme on unstructured meshes for ideal MHD equations. As the meshes move along with the fluids in Lagrangian computation, this method would capture and describe the material interface and shock discontinuities automatically and precisely. Based on the geometry conservation, momentum and total energy conservation and magnetic flux conservation, a compatible nodal approximate Riemann solver is constructed via discrete entropy inequality. The conservative variables are piecewise linear reconstructed to increase spatial discretization accuracy and predictor-corrector time discretization method is

adopted in our scheme. The magnetic divergence constraint is satisfied by using the generalized Lagrangian multiplier method, which propagates and dissipates the magnetic divergence error to the computation boundaries. Moreover, parallel computing is conducted on our scheme by exchange information of the boundary cells of each neighbouring block. Various numerical tests verify and validate the accuracy and robustness of our scheme.

Speaker: Xiao XU
Dr. Xiao Xu has got a Doctor of Science degree, specializing in computational mathematics. Currently, Dr. Xu works as a Postdoctoral Researcher at the Chinese Academy of Aerospace Aerodynamics.

Propulsion Systems and Components 3 (PSC 3)

Chairs: Dr. Inyoung YANG (KARI, Korea), Dr. Jun LIU (UNAA, China)

HiSST 2024 - 315

Design and Starting Study of the Adjustable Inward Turning Inlet at Ma1.5~7

Fuzhou LIU, Huacheng YUAN, Keyu ZHOU, Zhenggui ZHOU

Nanjing University of Aeronautics and Astronautics (NUAA), China

Aiming at the challenges of the strong three-dimensional feature and difficulty in variable geometry for inward turning inlet, a variable-geometry design method combining inward turning and secondary shock wave compression is proposed. The start ability of the variable-geometry inward turning inlet is studied by numerical simulation, and the reason for reducing the start Mach number is analyzed. The results show that the Mach number range of the inlet start at the fixed-geometry state is broadened from Ma=3.5~7 to Ma=3~7, compared to the original inward turning inlet. Besides, the variable-geometry method of rotating the secondary compression surface enables the inward turning inlet to operate with the start state at Ma=1.5~2.5. Combined with the analysis of the isentropic criterion, it is found that the variable-geometry inward turning inlet proposed in this paper mainly improves the start capability by reducing both the mass flow coefficient and the total contraction ratio, thus realizing the inlet start at Ma=1.5~7.

Speaker: Fuzhou LIU
Liu Fuzhou is a Ph.D. student at the College of Energy and Power Engineering, Nanjing University of Aeronautics and Astronautics, China

HiSST 2024 - 034

Design of a Truncated Ideal Nozzle for a Re-usable First Stage Launcher

Sebastian KARL, Tamas BYKERK, Mariasole LAURETI

DLR - Institute of Aerodynamics and Flow Technology, Germany

This paper presents the design of a truncated ideal nozzle (TIC) for the RFZ model, a generic, open source geometry of a re-usable launcher in vertical take of - vertical landing (VTVL) configuration. This new nozzle is designed for methane fueled engines, to be more in line with current trends for re-usable launch systems. The design methodology is presented, along with some internal flow calculations which compare the new shape with the existing nozzle which has a parabolic thrust optimized (TOC) contour. It was found that at the same expansion ratio, the performance of the new nozzle is identical to the existing parabolic one. As expected, the TIC-design results in a slight elongation of the nozzle extension. Due to the absence of internal shocks and the resulting smooth outflow profiles the TIC configuration is considered to be more robust for the present standard test cases and outflow profiles are easier to implement in setups for CFD-rebuilding. The geometry of the new nozzle and results are made openly available to the research community to promote collaboration in understanding the design challenges associated with re-usable launchers.

Speaker: Sebastian KARL
Dr. Sebastian Karl is a research scientist at the DLR Institute for Aerodynamics and Flow Technology in Göttingen. 24 years of experience in the development and application of numerical models and methods for hypersonic reacting flows and combustion. Current research interest focused on re-usable space launch systems.

HiSST 2024 - 110

High Fidelity Simulation of Liquid Jet Breakup in Supersonic Crossflow

DongGyu YUN, Hong-Gye SUNG

Korea Aerospace University (KAU), Korea

The liquid break-up and spray combustion in supersonic crossflow are primarily encountered in scramjet engines. An aerated liquid jet injector can be considered as the effective way enhancing the liquid break-up and atomize in certain time. The atomization characteristics by varying the gas liquid ratio (GLR), which represents the ratio of gas to liquid in the aerator, is investigated. The numerical results are compared with the experimental data for GLR 0%, 4%, and 8%. This study aims to provide a comprehensive simulation of the processes of ligament and droplet breakup and atomization, employing the homogeneous mixture model (HMM) and large eddy simulation (LES). Furthermore, numerical techniques are applied, including the Novel-Abel Stiffened Gas (NASG) state equation, Adaptive Mesh Refinement (AMR), Synthetic Eddy Method (SEM), and the Eulerian-Lagrangian (EtoL) transformation.

Speaker: DongGyu YUN
Affiliation and Position: Korea Aerospace University
Education and Degree: Ph. D. Student

HiSST 2024 - 333

IDDES Modeling of a Dual-mode Scramjet by Dynamic Zone Flamelet Model with Sensitivity Analysis of Zoning Parameter

Zheng ZHANG, Wei YAO

Institute of Mechanics, Chinese Academy of Sciences (IMCAS), China

Based on the dynamic zone flamelet model (DZFM), the turbulent combustion of the dual-mode scramjet with a cavity stabilizer is numerically studied by IDDES. Sensitivity analysis of the reacting related scalars is conducted previously to determine the appropriate zoning configurations. The jet wake and cavity stabilized flame modes occurred with increasing cross flow temperature are well reproduced with modeling. The heat release rate and reaction progress variable are recognized as vital zoning parameters to capture the cavity-stabilized mode dominated by premixed flame. For the jet-wake stabilized flame, the dynamic zone simply divided by mixture fraction and geometric coordinates is acceptable.

Speaker: Zheng ZHANG
Dr Zheng ZHANG received his PhD in 2020 from University of Science and Technology. From 2024, he is assistant professor at Institute of Mechanics, Chinese Academy of Sciences. His research area mainly includes modeling of supersonic turbulent flame and flame stability in micro-scales.

HiSST 2024 - 058

LES Investigation of Thermally Choked Mode Combustion Characteristic of the Dual Combustion Ramjet Engine

Min-Seon JO[1], Bu-Kyeong SUNG[1], Seung-Min JEONG[2], Jeong-Yeol CHOI[1]

[1]Pusan National University(PNU), Korea
[2]Korea Aerospace Research Institute (KARI), Korea

Numerical study is carried out to investigate the combustion characteristics of the Dual Combustion Ramjet (DCR) engine. In this study, the two different combustion modes were achieved by differences in initial internal energy. These two combustion modes result from the interplay of compressibility effects, turbulent motion, pressure waves, and heat addition. The choice between modes depends on the level of heat addition and the presence of pressure wave interactions. It is inferred that mode control based on ignition sources is feasible in DCR. The ignition source could potentially involve a micro-pulse detonation engine, known for its capability to provide a high-energy supply.

Speaker: Min-Seon JO
Ms. Min-Seon Jo is a 3rd-year Ph. D Student of Rocket Propulsion Laboratory (RPL) at Pusan National University, Korea. She is engaged in various research areas, including numerical analysis of coaxial supersonic combustor (DCR), system engineering, rocket trajectory analysis. In this presentation, she aims to describe the LES Investigation of Thermally Choked Mode Combustion Characteristic of the Dual Combustion Ramjet Engine.

HiSST 2024 - 120

Numerical Study on Post-Combustion Chamber Impact on Hybrid Rocket Performance

Andrija DABANOVIC, Joël MARTIN, Stefan MAY, Viola WARTEMANN

German Aerospace Center (DLR), Germany

Within the AHRES programme, the German Aerospace Center (DLR) is developing a software for the preliminary design of complete hybrid and solid rocket engines. To validate the calculations, test firings are performed at DLR-site Trauen and numerical simulations are conducted with the DLR TAUCode. This study analyses the effect of the post-combustion chamber design on the combustion efficiency in hybrid rocket propulsion. It focuses on several key aspects including engine design, mesh convergence and the evaluation of overall combustion efficiency. Numerical analysis is performed in two-dimensional, axisymmetric simulations, including fuel mass flow and detailed combustion modelling. The engine design depends on a large number of parameters. Hence, the results of this study shall derive design recommendations to enhance size and weight of the propulsion system while keeping the combustion efficiency on a sufficient level.

Speaker: Andrija DABANOVIC
Mr. Andrija DABANOVIC is a Scientific Employee at German Aerospace Center, Institute of Aerodynamics and Flow Technology, Department Spacecraft. Focussing on the design, construction, testing and analysis of hybrid rocket engines at the institut's test bench in Trauen, Germany. Also conducting numerical simulations of the flow and combustion in hybrid rocket engines.

Propulsion Systems and Components 4 (PSC 4)

Chairs: Prof. Bok Jik LEE (SNU, Korea), Prof. Antonella INGENITO (Sapienza, Italy)

HiSST 2024 - 076

Knowledge Discovery on Cavity-Based Scramjet Combustor Design via Stochastic-Surrogate-Assisted Multi-Objective Optimization

Chihiro FUJIO[1], Sasi Kiran PALATEERDHAM[2], Lakshmi Narayana Phaneendra PERI[2], Hideaki OGAWA[1], Antonella INGENITO [2]

[1]Kyushu University, Japan
[2]La Sapienza University of Rome, Italy

Scramjet engine is a promising candidate for a propulsion system for hypersonic flights that is experienced in high-speed point-to-point transportation and space transportation. Even though the scramjet technology reached the level of successful in-flight operation, scramjet combustor design remains challenging, including significant costs for numerical simulations. While multi-objective optimization is one of the ideal approaches for design exploration, substantial costs for function evaluations drive the combustor design optimization unrealistic. The present study aims to enable highfidelity design exploration of scramjet combustors. As a preliminary study, this paper reports the results of data mining and model-based optimization based on a relatively small dataset of scramjet combustor CFD. Key design factors have been revealed including (1) the desirable flow structure in the vicinity of the cavity and the secondary injector and (2) influential design parameters to improve mixing efficiency, combustion efficiency, pressure rise, and thrust, respectively. In the end, a discussion is provided on the surrogate modeling available with a relatively small number of reacting flow CFD simulations.

Speaker: Chihiro FUJIO
Mr. Chihiro Fujio is a Ph.D. candidate at Kyushu University, Japan. His research focuses on scramjet engine design. He is currently working on deep learning and multi-objective design optimization. He also takes interest in data mining and sensitivity analysis for design and knowledge discovery.

HiSST 2024 - 081

Numerical Study of Vitiation Air Effects on the Hydrogen-fueled Direct-Connect Scramjet Combustor

Seung-Min JEONG, Jae-Eun KIM, Mun-Soo KIM, Jeong-Yeol CHOI

Pusan National University (PNU), Korea

This study numerically investigates the combustion characteristics of a direct-connect scramjet combustor depending on the incoming vitiation air effects. A high-resolution comprehensive numerical simulation was conducted with hybrid LES/RANS and high-order schemes. Two different equivalence ratios, 0.23 and 0.45, were imposed on each incoming condition, clean air and vitiation air, to investigate the effects of equivalence ratio changing. The results show that shock trains accompanied by a thermal chocked formed near the cavity close-out region when the incoming flow condition changes from vitiated air to clean air. The change in combustion characteristics depending on the incoming air was found to be more severe as the equivalence ratio increased. Present results indicate that when the ground experimental test with the vitiated air heater to derive the design point of a scramjet combustor or engine, results must be calibrated considering the discrepancies between the combustion characteristics of the clean and vitiated air.

Speaker: Seung-Min JEONG
Affiliation and Position:
- (~2024.02) Pusan National University (PNU)
- (2024.01~) PostDoc. researcher at Korea Aerospace Research Institute (KARI)

HiSST 2024 - 130

Thermally Choked Nozzle 1D Model for Low-Mach Dual Mode Scramjet Performance Assessment

Jean-Etienne DURAND, Frédéric OLIVON

Office National d'Etudes et de Recherches Aerospatiales (ONERA), France

Beyond the flight Mach number 7, the scramjet, with supersonic combustion, shows higher performances than the ramjet, with subsonic combustion, due to the substantial pressure losses, chemical dissociation effects, and high thermomechanical stresses. The dual-mode scramjet would be a solution to hold optimal performances over an extensive range of flight Mach numbers. The use of a divergent nozzle choked flow through a thermal throat, generated by heat combustion, turns out to be an elegant approach to switch from subsonic to supersonic combustion processes, avoiding mechanical constraints and complex systems. Furthermore, compared with conventional ramjet, this approach increases the allowable mass flow rate through the engine, increasing the thrust. However, to design such a combustion chamber configuration, the flow and performances require to be modeled according to the characteristics of the combustion, the turbulence, and the significant variations of the thermos-physical properties. The present work aims to develop a quasi-one-dimensional steady model of a thermally choked nozzle flow (TCNF) to improve the quasi-one-dimensional model of a dual-mode scramjet and to predict the performances. Three approaches are assessed according to assumptions on thermos-physical properties, the friction effects, and the aerothermal flow. Numerical simulations, computed with CEDRE, the ONERA CFD software, will be carried out to validate the obtained results in the quasi-one-dimensional model. The impact of mass flow rate and equivalence ratio is studied. The turbulent boundary layer impact, via friction, on the thermal throat position is also regarded.

Speaker: Jean-Etienne DURAND
Dr. Jean-Étienne Durand is a researcher and engineer at ONERA, focused on the aerothermodynamics of combustion chambers for aerospace engines, such as hybrid rocket engines and turbofan/turbojet engines.

HiSST 2024 - 368

The Red Kite Sounding Rocket Motor Qualification Milestones and Application Spectrum

F. SCHEUERPFLUG[1], T. RÖHR[1], T. HUBER[1], M. REINOLD[1], D. HARGARTEN[1], L. KOBOW[1], R. KIRCHHARTZ[1], M. KUHN[2], A. Weigand[2], M. BERNDL[2], J. WERNETH[2]

[1]DLR Mobile Rocket Base, Germany
[2]Bayern-Chemie GmbH, Germany

The Red Kite© is a commercially available, serially produced solid propellant sounding rocket motor in the class of one ton of net explosive mass. It was developed in response to a sustained demand from the scientific community for high performance sounding rocket vehicles. The Red Kite is primarily designed to be employed as a powerful booster for military surplus and commercial second stages, but can also be used as a sustainer when boosted by either an even larger motor or by another Red Kite. Typical payloads will range between 200 to 600 kg. When used in a mission design tailored to microgravity research, typical apogees range between 250 to 300 km, while the needs of the hypersonic community can be met by a suppressed trajectory design,

typically providing horizontal flight at Mach numbers between 6 to 9 in the altitude band 30 to 60 km. Following a Phase A definition study in 2017, the German Aerospace Center DLR contracted Bayern-Chemie GmbH in 2020 for the development and manufacturing of the Red Kite motor, initially providing 30 serial units. Subsequent to preliminary design and materials selection phase, ground testing of mechanical, pyrotechnical and electrical subsystems was conducted. Finally, two full scale qualification motors were successfully test-fired in August 2023 at ESRANGE Space Center, with the test models tempered to the upper and lower limits of the operational temperature envelope after having completed a rigorous protocol of thermal cycling and mechanical vibration representative of loads to be expected during handling, transport and flight. Following the successful qualification, serial production was initiated and serial motor number one released for a maiden flight from Andøya Space Center in November 2023, proving the design in flight successfully. The paper gives a summary of the motor performance, aspects of the system design, the qualification program and its application spectrum in active and future sounding rocket vehicles.

Speaker: Frank SCHEUERPFLUG
Mr. Frank Scheuerpflug is an Aerospace Engineer working at German Aerospace Center's Mobile Rocket Base. Responsible for launch service provision of 10 sounding rocket research missions annually.

HiSST 2024 - 037

Experimental and Numerical Research on a Design Concept of Two-stage Compression Inward-turning TBCC Inlet

Zhancang HU[1], Yiqi TANG[1], Zhonglong LI[2], Zejun CAI[1], Zhenqi SUN[1], Chengxiang ZHU[1], Yancheng YOU[1]

[1]Xiamen University, China
[2]AECC Sichuan Gas Turbine Establishment, China

The inlet system plays a vital role in achieving the wide speed range flight based on the Turbine-Based Combined Cycle (TBCC) propulsion system. Developing reliable design methods and conducting detailed experimental studies for the TBCC inlet is imperative. In this paper, an inward-turning TBCC inlet working within Ma∞=0~4 was designed based on the two-stage compression basic flow field, and wind tunnel tests were conducted on a scaled model at the design point and several off-design points. The schlieren system and pressure acquisition system were employed to capture the flow structure and record the pressure data. At Ma∞=4, experimental pressure ratio distributions along the upper wall agree well with the numerical results, demonstrating the two-stage compression shock wave structure and validating the design concept. The maximum back pressure ratio and critical total pressure recovery coefficient were 76.56 and 0.506 at the design point, respectively, agreeing well with the simulation results of 76.03 and 0.505. Furthermore, during the tests, the inlet can start and work stably under subsonic Ma∞=0.8, supersonic Ma∞=2, and Ma∞=3, exhibiting good aerodynamic performance. These experimental results reveal the working characteristics of the inward-turning TBCC inlet within the wide speed range and effectively validate the design concept of the inlet employed in this work, promoting its engineering application.

Speaker: Zhancang HU
Mr. Zhancang Hu is a doctoral student at the School of Aerospace Engineering, Xiamen University

HiSST 2024 - 180

Observation of Hydrogen Combustion Characteristics in a Scramjet Combustor Based on Cavity Type

Geon Wook YIM, Hyoung Jin LEE

Inha University, Korea

In a scramjet combustor, combustion characteristics were observed based on the L/D ratio of the cavity under equivalent equivalence ratio conditions. Combustion experiments were conducted at a Mach number of 2.0 and a pre-temperature of 1400 K inside the combustor. Hydrogen was used as the fuel, and the L/D ratios of the cavity were set at 7 and 12. The equivalence ratio was maintained at 0.4. The experimental results revealed a mode transition at L/D ratios of 7 and 12. At L/D 12, a mode transition occurred between cavity shear-layer stabilized combustion and cavity shear-layer/recirculation stabilized combustion. At L/D 7, a similar combustion mode transition occurred as at L/D 12, but the Jet-wake combustion mode also manifested. According to the experimental results, under the same equivalence ratio, L/D 12 exhibited more stable characteristics.

Speaker: Geon Wook YIM

Geon Wook Yim is a Ph.D. candidate at Jet Propulsion Laboratory in Inha university. His research focuses on the supersonic combustion.

High-Speed Missions and Vehicles 2 (HSM 2)

Chairs: Dr. Michael SMART (Hypersonix Launch Systems Ltd, Australia), Dipl.-Ing. Marius FRANZE (DLR, Germany)

HiSST 2024 - 220

Experimental Aeroshape Characterization of an Inflatable Heat Shield Re-entry Vehicle in the EFESTO-2 Project

Junnai ZHAI[1], Thomas GAWEHN[1], Ali GÜLHAN[1], Ysolde PREVEREAUD[2], Yann DAUVOIS[2], Giuseppe GUIDOTTI[3], Giuseppe GOVERNALE[4]

[1] German Aerospace Center (DLR), Germany
[2] Office National d'Etudes et de Recherches Aerospatiales (ONERA), France
[3] Deimos Space S.L.U, Spain
[4] Politecnico di Torino, Italy

Inflatable Heat Shields (IHS) represent a breakthrough solution that supports the realization of innovative re-entry space missions by significantly increasing payload capability and enhancing space systems' recovery potential. To make this solution operational, several key technologies must be matured to an appropriate level. Within the scope of the EFESTO-2 project, structural and aerodynamic ground tests have been planned to advance our understanding of this unique inflatable aerodynamic decelerator system. To achieve this objective, a numerical study is conducted to simulate the maximum expected deformation level of the heat shield during re-entry. Subsequently, both nondeformed and deformed shapes of the heat shield are tested in the H2K and TMK wind tunnels. Following this, post-test numerical analysis will be conducted. This paper presents the efforts and achievements pertaining to the aerodynamic investigation of aero-shapes in the hypersonic wind tunnel H2K and the supersonic wind tunnel TMK. It encompasses aspects such as the specification of wind tunnel models, test conditions, measurement techniques, and the evaluation of test results.

Speaker: Junnai ZHAI
Dr.-Ing. Junnai Zhai is a Scientist at the German Aerospace Center (DLR), specializing in the Department of Supersonic and Hypersonic Technologies.

HiSST 2024 - 071

Progress in Progress Pre-definition of the SpaceLiner 8 Advanced Hypersonic Transport

Martin SIPPEL, Jascha WILKEN, Leonid BUSSLER, Steffen CALLSEN, Tommaso MAURIELLO

DLR Space Launcher System Analysis (SART), Germany

The SpaceLiner ultra-high-speed rocket-propelled passenger transport is in Phase A conceptual design after successful completion of the MRR. The ongoing concept evolution is addressing system aspects of the next configuration release 8. The space transportation role of the SpaceLiner concept as a TSTO-launcher is further refined and suitable precursor steps are investigated. The SpaceLiner cabin integration is an important aspect to be addressed as well as the feasibility of performing multiple missions compliant with noise and sonic-boom constraints. The passenger and orbital stage concepts are evaluated by Multi-Disciplinary Design Analyse and Optimization.

Speaker: Martin SIPPEL
Dr. Martin SIPPEL is a head of DLR space launcher system analysis (SART) decades experience in preliminary sizing and analysis of reusable launch vehicles (RLV) and hypersonic transport vehicles former lecturer space propulsion.

HiSST 2024 - 219

Numerical Aero-shape Characterization of an Inflatable Heat Shield Re-entry Vehicle in the EFESTO-2 Project

Ysolde PREVEREAUD[1], Yann DAUVOIS[1], Junnai ZHAI[2], Thomas GAWEHN[2], Giuseppe GUIDOTTI[3], Giuseppe GOVERNALE[4]

[1]ONERA/DMPE, France,
[2]German Aerospace Center (DLR), Germany
[3]Deimos Space S.L.U, Spain,
[4]Politecnico di Torino, Italy

Inflatable Heat Shields (IHS) are considered as a breakthrough solution to support realization of innovative re-entry space missions as a significant increase of payload capability and space systems recovery. For this solution to become operational, a number of key technologies must be matured towards an appropriate level. In the frame of the European EFESTO-2 project, structural and aerodynamic ground tests are planned to improve knowledge of this peculiar inflatable aerodynamic decelerator system. To reach this goal, a numerical study is carried out to simulate the maximum expected deformation level of the heat shield during the re-entry. Then, undeformed and deformed shapes of the heat shield are tested in the H2K and TMK wind tunnels, followed by post-test numerical rebuilding. This paper presents pre-numerical investigation pointing out the definition of the test articles and the test campaigns, as well as post numerical rebuilding of TMK test experiments with numerical-experimental cross-checks.

Speaker: Yann DAUVOIS

Dr. Yann DAUVOIS is a research scientist from ONERA Toulouse in France. Dr. Yann DAUVOIS's activities are focused on solving rarefied flows around rockets, vehicles or debris to anticipate the rarefaction effects which influence a flight at high altitude (like re-entry). In the context of the EFESTO project, ONERA is involved to characterise the pre-flight, the post-flight and the numerical rebuilding of the wind tunnel test compaign of the Hypersonic Inflatable Aerodynamic Decelerator concept.

HiSST 2024 - 353

Establishment of System Engineering Procedure for Two-Stage Sounding Rocket

Si-Yoon KANG, Min-Seon JO, Joungsu OH, Inhoi KOO, Keon-Hyeong LEE, Jeong-Yeol CHOI

Pusan National University (PNU), Korea

The growth of the space economy and the success of space missions rely heavily on the development of space transportation technology. The continuous and effective development of space transportation technology relies on the education of human resources nurturing practical talent with both theory and experience. The SLV·ST project was started to provide graduate students with hands-on experience developing launch vehicles through systems engineering. Present paper presents a case study of the application of system engineering principles in the development of systems of SLV·ST project. The SLV·ST project requirements were established using a tree structure referring to the open resources, those will be followed by the development, test and launch of two-stage sounding rocket. The SLV·ST project will provide valuable experience in systems engineering to future aerospace professionals and enhance their understanding of the process. This work would serve as a foundation for the continued growth and development of the spacecraft and space transportation industries.

Speaker: Si-Yoon KANG

Mr. Si-Yoon KANG is a Ph.D student at Pusan National University, studying systems engineering.

HiSST 2024 - 100

First Hot Combustion Subsonic Retro Propulsion Tests in the Vertical Free Jet Facility Cologne (VMK)

Ansgar MARWEGE, Daniel KIRCHHECK, Ali GÜLHAN

German Aerospace Center (DLR e.V.), Germany

High uncertainties exist in modelling subsonic retro propulsion flow fields with CFD. For example, the choice of the turbulence model can greatly influence the flow field and the resulting heat loads. Hence, experiments with hot oxygen/hydrogen exhaust plumes and active counterflow are indispensable for the understanding of these flow fields. In the frame of the Horizon 2020 project RETALT, first subsonic retro propulsion experiments with oxygen/hydrogen combustion have been performed in the Hot Plume Testing Facility (HTPF) which consists of the Vertical Free Jet Facility Cologne (VMK) and an oxygen/hydrogen supply infrastructure. Oxidizer fuel ratios of around 0.7 were tested at Mach numbers of 0.6, 0.7, 0.8 and 0.9. The stagnation pressures in the model were around 21 bar. The steady and unsteady flow field features were analysed with regular video recordings, schlieren and infrared recordings. Furthermore, the pressures and temperatures in the base area were evaluated. The tests are compared to earlier cold gas tests of the same configuration. The steady flow field features are similar to those in cold gas test. However, the unsteady features prove to be very different. A general tendency of the dependence of the plume length on the momentum flux ratio, found in could gas tests, can be confirmed. However, the plume length is larger in the hot tests. The dominant frequencies found in cold gas tests in the modes of the Schlieren recordings differ from those found in the hot gas tests. Due to current trends in the European launcher designs towards the use of oxygen/methane engines, in the future, methane experiments are foreseen and an improved model concept shall enable higher oxidizer fuel ratios and, therefore, a better similarity to the flight conditions.

Speaker: Ansgar MARWEGE
Mr. Ansgar Marwege is research scientist at the Supersonic and Hypersonic Technologies Department of the German Aerospace Center, DLR, in Cologne. His research area is the investigation in reusable launcher configurations with a focus on vertical landing with the aid of retro propulsion, the configuration layout, the aerodynamic design and the testing in the aerodynamic wind tunnel facilities.

HiSST 2024 - 250

Multidisciplinary Analysis Framework for The Mission Design of Reusable Space Transportation Re-Entry Vehicles

Federico TOSO, Giovanni MEDICI, Jacopo GUADAGNINI, Gabriele DE ZAIACOMO

Deimos Space S.L., Spain

Analysing space access and re-entry missions is complex, demanding a multidisciplinary approach to meet diverse requirements while adhering to strict constraints. Disciplinary synergies help minimize early challenges, optimizing outcomes. Each mission is unique, requiring precision from swift estimations to intensive simulations. The multi-fidelity and multi-disciplinary framework developed by the Atmospheric Flight Competence Centre is designed to tackle such challenges. This paper delves into its components and methodologies, testing, and latest Multidisciplinary Design Optimization developments, emphasizing the topics of aeroshape generation, trajectory optimization, and aerodynamics. These tools are critical for the design of reusable re-entry vehicles, enabling safe and controlled descents within the mission constraints. Real-world case studies showcase the framework's adaptability and effectiveness in addressing mission-specific challenges.

Speaker: Federico TOSO
After the Polytechnic University of Turin, and the Doctorate at the University of Strathclyde, I joined Deimos Space where I lead the optimisation developments of the Atmospheric Flight centre, focusing on present and future launch vehicles.

Chairs: Dr. Jan MARTINEZ SCHRAMM (DLR, Germany), Dr. Ajmal MOHAMED (ONERA, France)

HiSST 2024 - 277

Temperature Sensitive Paint Techniques for Ultra High Speed Acquisition their Development towards the Determination of Flight Temperatures

Jan MARTINEZ SCHRAMM, Divek SURUJHLAL, Leni SCHMIDT

German Aerospace Center (DLR), Germany

Surface-mounted temperature sensors like thermocouples or thin film gauges are commonly used in high enthalpy impulse facilities with the goal of the precise determination of the surface heat flux into wind tunnel models. The High Enthalpy Shock Tunnel Göttingen, HEG, is one of the major European hypersonic test facilities of this kind. The test time in such facilities in general and for experiments in HEG in special is typically in the ms range, which requires measurement techniques with high acquisition rates and high precision and resolution at the same time, because the precise determination of the surface heat flux is mandatory for experiments in high enthalpy impulse facilities [1]. Thermocouples and thin film gauges guarantee fast response times in the order of a few microseconds and therefore a high temporal resolution. But the spatial resolution is limited and can only be increased by increasing the number of sensors installed in a wind tunnel model. Additionally, it is challenging to attach sensors on complex or sharp-edged models. A very promising but experimentally challenging non-intrusive option is the use of the temperature-sensitive paint technique (TSP). The application of TSP enables the measurement of spatially resolved surface temperatures which allow for the subsequent calculation of surface heat fluxes. The development of this technique with a special focus on high repetition rates due to the typical measurement times of ms will be reviewed in this paper and the application possibilities will be outlined. Selected applications in HEG over the last decade will be discussed and the newest development of the TSP towards high temperatures which are encountered in flight will be presented and results of an application will be shown.

Speaker: Dr. Jan MARTINEZ SCHRAMM
Dr.rer.nat. Physics at University of Göttingen in 2008 - Head of Spacecraft Department Institute of Aerodynamics and Flow Technology since 2021 - Experimental High Temperature Gas Dynamics

HiSST 2024 - 123

Initial Investigation of a Combustion-Driven Shock Tunnel Operating as a Shock Tube

Marco A. S. MINUCCI, Israel S. RÊGO, Marcos M. BORGES, Giannino P. CAMILLO, Lucas A. G. RIBEIRO, Rafael O. SANTOS, Thiago L. DE ASSUNÇÃO, Ivo de P. M. ALVES, Thiago V. C. MARCOS, Bruno B. NASCIMENTO, Pedro S. MATOS, Lucas GALEMBECK, Dermeval CARINHANA JR

Institute for Advanced Studies (IAS), Brazil

A new high-enthalpy hypersonic pulsed facility is being commissioned at the Aerothermodynamics and Hypersonic Division – EAH of the Institute for Advanced Studies – IEAv, in Brazil. The single-diaphragm combustion-driven shock tube operating mode was initially investigated. Both driver and driven sections were instrumented with pressure transducers. The combustion driver was filled with a pressurized stoichiometric mixture of Hydrogen and Oxygen diluted in Helium, which was ignited through specially built spark plugs evenly distributed along the driver tube wall. Mixture dilutions of 65% and 75% were investigated with filling pressure up to 3.0 MPa. The shock tube performance was also evaluated in terms of incident shock wave velocity.

Diaphragm rupture behaviour was assessed for several operational conditions, in order to minimize diaphragm debris formation and to guarantee repeatable flow conditions. In addition, the combustion-driven shock tunnel safety procedures were practiced starting from milder configurations before ramping up the operating conditions.

Speaker: Dermeval CARINHANA JR
Senior Researcher at the Institute for Advanced Studies, IEAv. Former head of the Aerothermodynamics and Hypersonics Division. Currently, the Head of the Technical Directory of IEAv and Deputy Manager of the brazilian hypersonic vehicle, "14-X".

HiSST 2024 - 195

Tailored Operating Conditions in the T6 Reflected Shock Tunnel

Joshua ASHBY, Matthew MCGILVRAY

University of Oxford, UK

Reflected shock tubes are used extensively to study a range of high enthalpy aerothermodynamic phenomena, typically associated with hypersonic flight. A reflected shock is utilised to produce a region of stagnated high-pressure gas which flows through a converging-diverging nozzle. The test time is defined by the duration of steady conditions in the stagnated supply region, typically on the order of 1-10ms [1]. This necessitates a method for increasing the duration of steady supply conditions through a process known as contact interface tailoring. A tailoring method based on a state-to-state equilibrium thermochemistry solver is described which maintains the reflected shock strength across the driver and test gas. The method is applied to an Earth re-entry condition, and validated through a shot conducted within the T6 Stalker Tunnel in RST mode.

Speaker: Joshua ASHBY

HiSST 2024 - 384

Development of an Approach that Delivers a High-Tempo of High Speed Flight Trials at Affordable Costs

Allan PAULL, Jens KUNZE, Sampada SHELAR, Nathan PAULL, Tom WATTS

The University of Queensland (UQ), Australia

Although the Australian flight programs HyShot, HyCAUSE and HIFiRE successfully achieved hypersonic flight testing at a third of the cost of the typical flight program at the time, to successfully demonstrate components and systems applicable to high speed flight, a high tempo of demonstrations that can be achieved at even lower costs needs to be possible. In addition, a pipeline of talent to continue to specifically support flight demonstrations and ultimately development of marketable systems needs to be established. At the University of Queensland, the challenge of developing such an approach has been undertaken. A flight program, STAje-, was initiated to demonstrate high speed electric propulsion, but also to meet this challenge. This presentation provides details of the approach that has evolved. It includes a description of the approach to payload development and manufacture, as well as rocket motor design and the importance of an independent range with land recovery.

Speaker: Allan PAULL
I was the Technical Lead to the HIFiRE, HyCAUSE and HyShot flight programs. I am currently working on the STAJe- flight program to demonstrate high speed electric flight.

HiSST 2024 - 182

Drag due to Distributed Roughness in Supersonic Turbulent Boundary Layers: Comparison between Experiments and Numerics

Quentin CHANZY[1], Sylvain MORHILAT[2], Antoine DURANT[1], Vincent BRION[2]

[1]MBDA, France
[2]ONERA, France

The purpose of this paper is to present the design of a test bench and the subsequent test campaign conducted in an effort to measure the extra drag due to a rough surface in a supersonic flow. Using this test bench, the drag associated with roughnesses sizing from ~1µm to 65µm, generated by commercial sand papers, has been tested in the ONERA R1Ch wind tunnel at Mach number 3. Reynolds Averaged Navier Stokes simulations of the flow have been conducted taking into account the roughness contribution through a roughness correction model. The numerical and experimental results are compared and the link between the size of the roughness and the equivalent sand grain roughness is discussed.

Speaker: Quentin CHANZY
Studied at ENS Paris Saclay, University of Southampton. PhD at Ecole Polytechnique and ONERA on Optimization of fluidic control in a transonic channel flow. Work at MBDA

HiSST 2024 - 132

The Dynamic Test of the Longitudinal Stage Separation for the Parallel-staged Two-stage-to-orbit Vehicle in Shock Tunnel

Yue WANG, Yun Peng WANG

Institute of Mechanics, Chinese Academy of Sciences (IMCAS), China

Parallel-staged two-stage-to-orbiter (TSTO) vehicle is one of the promising next-generation reusable launch vehicles and comprises the booster and the orbiter. However, the TSTO hypersonic stage separation introduces strong shock waves and results in complex aerodynamic interaction into the interstage flowfield, which increases the risk of the stage separation and would determine the success of the launch mission. Thus, the longitudinal stage separation (LSS) is proposed, in which the orbiter accelerates along the upper surface of the booster with the unnoticeable interstage gap, so the strong shock-shock interaction (SSI) might be absent in the interstage flowfield. The dynamic tests of the TSTO stage separation are conducted in the JF-12 hypersonic flight condition duplicated shock tunnel at Mach 7. The TSTO vehicle comprises the wave-rider and the spaceplane as the booster and the orbiter. The dynamic test methodology of the multi-body vehicle stage separation in the short effective test time ground facility is clarified, including the high-speed pneumatic ejection to launch vehicle model system (HPELS) to make the LSS and high-speed Schlieren visualization and image processing techniques to capture the separation trajectory. Besides, the unsteady shock wave structure and wall pressure are also observed and examined. The LSS of the TSTO vehicle in the JF-12 shock tunnel is examined at angles of attack (AoA) of 8.3 and 4.5 deg. The results show that the small interstage gap of LSS leads to weak type I and VI SSI, with short-duration weak shock reflections at a high AoA. Furthermore, no shock reflection is observed at a small AoA. Additionally, no stage re-contact is observed, and the safety and feasibility of the LSS principle for the parallel-staged TSTO vehicle are demonstrated.

Speaker: Yue WANG
Yue WANG is a Ph.D. candidate at the Institute of Mechanics. He specializes in investigations of high-speed flow problems including aerodynamic interactions between multi-body, free-flight experiments in hypersonic shock tunnels, unsteady flow, and so on.

Materials and Structures 2 (M&S 2)

Chairs: Prof. Ikhyun KIM (Keimyung University, Korea), Dr. Jonathan RAYNAUD (MBDA, France)

HiSST 2024 - 340

Design and Post-Test Analysis of PWT Testing on CMC and UHTCMC Materials

Giuseppe Maria INFANTE[1], Leonardo Luca MELLONE[1], Daniele GUIDA[1], Carlo PURPURA[1], Mario DE STEFANO FUMO[1], Alessandro AIROLDI[2], Antonio Maria CAPORALE[2], Marco RIVA[2]

[1] Italian Aerospace Research Centre (CIRA), Italy
[2] Politecnico di Milano

The thermal protection systems for reusable space transport vehicles primarily rely on ceramic matrix composite materials, known as CMC (Ceramic Matrix Composites). C/SiC (Carbon/Silicon Carbide) represents a solution for the development of thermostructures capable of operating at temperatures up to 1600°C. In Europe, they have been developed in many Space Vehicle projects (X-38, EXPERT, IXV). To date, their usage needs to be verified for reusability within a structural philosophy that involves assigning increasingly significant structural tasks to C/SiC structures under conditions characterized by exposure to significant thermal fluxes for extended periods. The AM3aC2A project aims to develop numerical tools for multi-scale modeling dedicated to space-specific materials and their integration with experimental protocols to define a design methodology for reusable space thermal structures, not only considering C/SiC but also considering UHTCMCs, a new class of materials primarily based on matrices of metallic borides reinforced with carbon fibers and aim to achieve operating temperatures exceeding 2000°C. Challenges include complex material behavior and the need for conservative designs due to limited knowledge. Within the AM3aC2A project, the Italian Aerospace Research Centre (CIRA) has been involved to perform PWT design, testing and post-test analyses on the CMC and UHTCMC samples. The design and manufacturing phases of the TAs are already completed, while PWT testing is foreseen in the next months; the results will be included in the paper. Italy's involvement in this project enhances its capabilities in critical technologies and opens opportunities for a wide range of applications, from space propulsion to aviation, energy, and automotive sectors. By reaching Technology Readiness Level 5 (TRL 5), Italy can demonstrate its national capacity for designing and testing ceramic matrix composite components, fostering innovation and international competitiveness. The project holds great promise for future space programs and technological advancements in various industries.

Speaker: Roberto GARDI
Master degree and PhD in aerospace engineering in Naples University. Employed at the Italian Aerospace Research Center since 2005. He has worked on thermal protection systems and materials for atmospheric reentry, including rigid ceramics composite but also flexible TPS for both deployable and inflatable systems.

HiSST 2024 - 039

Temperature Effect on Erosion by Atomic Oxygen in LEO Environment Using Reax-FF Molecular dynamics

Jiwon JUNG, Jongkyung AN, Seunghwan KWON, Gun Jin YUN

Seoul National Univeristy (SNU), Korea

While operating spacecraft in Leo Earth Orbit (LEO), polymers are damaged by extreme environments in space. Especially, highly reactive oxygen atoms are continuously bombarded on the surface, leading to polymer erosion. In this study, atomic oxygen (AO) bombardment simulation on Kapton using Reax- FF molecular dynamics (MD) was undertaken to calculate erosion yield at the LEO-operating temperature regime and quantify temperature

dependency. Unlike previous studies under NVE ensemble, the convergence of erosion yield after saturation of AO on the system was observed, and from the Arrhenius plot of the erosion yield, the phase transition effect was also found by relatively long-time NVT simulations.

Speaker: Jiwon JUNG
Mr. Jiwon Jung is a Ph.D student of Seoul National University.

HiSST 2024 - 319

Acoustic Shock Wave-induced Phase Transition of Indium Selenide from Orthorhombic to Rhombohedral Crystal System

S. A Martin BRITTO DHAS[1, 2], S. OVIYA[1], F. IRINE MARIA BINCY[1], Ikhyun KIM[2]

[1]Abdul Kalam Research Centre, Sacred Heart College, India
[2]Keimyung University, Korea

Indium selenide is a semiconducting material that has a layer-by-layer crystal structure. The present work treats Indium selenide with dynamic shock waves using a Semi-automatic Reddy tube as 100, 200, 300, and 400 shock pulses. In4Se3 switched from orthorhombic to rhombohedral (α- In2Se3) phase at 100 shock pulses and remained in the same phase up to 400 shock pulses by applying 2.0 MPa of pressure and a temperature of 864 K. The crystal structure was examined using Powder X-ray diffraction, and Raman analysis. The morphology and optical properties of the material are investigated using Scanning Electron Microscope, and UV-DRS. The results from XRD and Raman confirm the phase transition through the formation and disappearance of the peak. While increasing the shocks, the morphology produces a layered shape, and optical investigation revealed that the band gap of the material changed from semi-conducting to insulator.

Speaker: S. A Martin BRITTO DHAS
Joint Professor, Brain pool fellow, Department of Mechanical Engineering, Keimyung University, Daegu. South Korea. Assistant Professor, Department of Physics, Sacred Heart College, Tiruapttur, Tamilnadu, India Research interests: Shock wave-material interactions, Shock tube experiments

HiSST 2024 - 342

Development of a Numerical Tool for Step & Gap Prediction on Space Rider Windward

Leonardo Luca MELLONE, Giuseppe Maria INFANTE, Mario De Stefano FUMO, Giuseppe Carmine RUFOLO

Centro Italiano Ricerche Aerospaziali (CIRA), Italy

The objective of the work is to predict the value of the Steps and Gaps among the windward shingles that could be a critical issue for re-entry vehicle. To achieve this goal efficiently, a computational cost-saving approach was adopted through the use of a homogenized model. The windward TPS (Thermal Protection System) consists of flat and curved shingles, as well as complex Hinge TPS elements, connected to the structure with an attachment system designed for rigidity, flexibility, and thermal insulation. The presence of discontinuities like protuberances, cavities, gaps, or steps on the vehicle's surface can impact the aerodynamic characteristics and heat transfer rates during high-speed flight, potentially leading to catastrophic consequences. The optimization of the Standoff's placement is crucial to mitigate in-flight deformations, which influence thermal flow behaviour and windward deformations.
The homogenization process involves accurately defining the mechanical and thermal properties of the structural components, specifically the Standoff, through iterative tuning. The analyses focus on monitoring results along the shingle edges and deformations along the contour. The homogenized model simplifies the

complex Standoff structure while maintaining accuracy, leading to reliable results in reduced timeframes.
The obtained results were validated through cross-validation with three-dimensional models, reducing the maximum average error to a few tenths of a millimetre. Conventions for step and gap definitions were established, and an algorithm was developed to obtain outcomes within the local reference system of each curved shingle edge element. Despite the introduction of some approximation in the results, particularly for Steps, they are considered reliable when calculated as average values and are consistent with 3D models and reference literature.

Speaker: Roberto GARDI
Name and Title: Roberto Gardi. PhD.
Affiliation and Position: CIRA Italian Aerospace Research Center. System Engineer.
Education and Degree: Master's degree and PhD in Aerospace Engineering.

HiSST 2024 - 183

A Study on the Mechanical Properties and Microwave Absorption Performance of Nickel-coated Basalt Fiber/aluminosilicate Ceramic Composite Applicable to Hypersonic Vehicle

Kwonwoo Park[1], Hoyoung Shin[1], Dongjun Hong[2], Hyunseok Ko[3], Jinhwe Kweon[1], Youngwoo Nam[2], Byeongsu Kwak[1]

[1]Gyeongsang National University (GNU), Korea
[2]Korea Aerospace University (KAU), Korea
[3]Korea Institute of Ceramic Engineering and Technology (KICET), Korea

In this study, a microwave absorbing structure that can implement stealth performance in a hypersonic environment was proposed. Basalt fiber and aluminosilicate with excellent heat resistance were selected to manufacture microwave absorbing structures, and nickel electroless coating was performed on basalt fiber to modify electromagnetic properties. Using CST-MWS, an electromagnetic field commercial program, a microwave absorbing structure was designed in the X-Band (8.2 - 12.4 GHz), and a microwave absorbing structure was manufactured through the autoclave process. The prepared specimen was evaluated by measuring the mechanical properties and microwave absorption performance in room temperature and ultra-high temperature environments. As the temperature increased, the microwave absorption performance decreased, but the absorption performance did not change significantly. It was also confirmed that the compressive strength increased as the amount of KOH mol constituting the geopolymer increased.

Speaker: Kwonwoo PARK

HiSST 2024 - 371

Thermophysical Properties of a High Density Carbon/Carbon Composite to Ultra-High Temperatures

Marco ATTIA, Wyman ZHUANG

Defence Science and Technology Group (DST Group), Australia

Carbon/Carbon composites are currently the material of choice for use on advanced thermal protection systems for high speed flight vehicles due to their excellent thermophysical properties and high specific stiffness and strength in hypersonic flight operational environments. The ultra-high thermophysical properties of carbon/carbon are essential for design purposes, especially where limited data exists for the temperature range of interest. To address this need, the thermophysical properties of a nominated high density carbon/carbon material were characterized. Properties such as specific heat, thermal diffusivity, thermal expansion and thermal conductivity for the material in all three material orientations (x, y, z) were investigated between ambient temperature to 2600°C.

The thermophysical assessment of the carbon/carbon composite is provided in two parts, the first set of thermal properties were determined for the material in its untreated state (no heat treatment), and the second set demonstrates the effect of heat treatment on the thermal properties. The Coefficient of thermal expansion (CTE), diffusivity as well as conductivity of the composite exhibit a distinctive shift in the material properties in the temperature range of 1300-1500°C. Subsequent thermal analyses beyond that temperature range is markedly different and therefore suggestive of the thermophysical properties which are to be expected should the composite be subjected to heat treatment. The microstructures changes of the carbon/carbon pre- and post-heat treatment were also examined by scanning electron microscopy/energy dispersive X-ray spectroscopy as well as optical microscopy. The findings are useful to assess the performances of the carbon/carbon composite in extremely high temperature conditions for the potential applications of hypersonic vehicle structure and components.

Speaker: Marco ATTIA

Mr Marco Attia is a Science Team Lead at the Defence Science and Technology Group located in Melbourne Australia. Marco has had a wide ranging experience, such as working as a stress analyst, conducting gas turbine engine performance modelling as well as developing a high-cycle fatigue testing capability in his role as a Propulsion Systems Engineer, to managing the Full-Scale Fatigue Test of the Hawk Mk127 Lead-In-Fighter conducted on behalf of the Commonwealth of Australia and BAE SYSTEMS UK. In most recent years Marco has been working to build an Extreme Environment Structural and Material thermophysical testing and characterisation capability in order to support Australia's Defence strategic priorities.

Hypersonic Fundamentals and History 1 (HFH 1)

Chairs: Prof. Ming DONG (IMCAS, China), Prof. Caihong SU (Tianjin University, China)

HiSST 2024 - 275

SWBLI Effects of Impinging Shock on a Flat Plate in High Mach Number Flows

Aishwarya PS, Mohammed Ibrahim SUGARNO

Indian Institute of Technology Kanpur (IIT Kanpur), India

The present work examines the shock-wave boundary layer interaction resulting from the impingement of an oblique shock wave, created by a 38-degree wedge, on a flat plate in a flow with a Mach number of six. The primary emphasis of the analysis is centered on the attainment of Mach reflection, wherein the Mach stem serves as a distinctive attribute for observing the Edney type II shock interaction occurring on the flat plate. Consequently, the establishment of a separation bubble, along with the accompanying phenomena of separation, reflected shock, and reattachment shock, occurs. The intensity of these phenomena varies depending on the vertical and streamwise distance at which the shock impinges on the flat plate. The experimental investigations in the Ludwieg tunnel and computational fluid dynamic analysis using the Ansys Fluent solver in laminar flow gives a comprehensive understanding of the flow. This research aimed to examine the two-dimensional implications of the observed occurrence.

Speaker: Aishwarya PS
Affiliation and Position: Student working in the Hypersonic Experimental Aerodynamics Laboratory at Indian Institute of Technology Kanpur, India
Education and Degree: Pursuing her master's in aerospace engineering.

HiSST 2024 - 280

Some Recent Developments in Hypersonic Flow Stability Analyses

Liang WANG, Song FU

Tsinghua University, China

This paper presents the authors' advancements in the investigation of flow instabilities encountered during hypersonic flight. It encapsulates several significant findings, as follows: 1) Elucidation of the excitation mechanisms governing the evolution of the three-dimensional boundary layer at the vehicle nose, with particular emphasis on the impact of thermal–chemical nonequilibrium effects. 2) Observation of a notable decay in disturbance growth-rate oscillation downstream of the turning point, where the unstable supersonic mode transitions back to the subsonic regime. 3) Discovery of novel modes of crossflow vortices occurring on the surface of swept wings.

Speaker: Linang WANG
Name and Title: Dr. Liang Wang
Affiliation and Position: Tsinghua University, Associate Professor
Education and Degree:
- Ph.D., Fluid Mechanics, School of Aerospace Engineering, Tsinghua University, China, Jul 2008
- B.S., Thermal Energy and Power Engineering, School of Aerospace Engineering, Tsinghua University, China, Jul 2003

HiSST 2024 - 175

Heat Flux Increment Induced by the Coupled Shear and Compression Effects in Laminar Hypersonic Flows

Huijun GAO, Zhi hui WANG

University of Chinese Academy of Sciences (UCAS), China

Shear and compression are basic effects in fluid motions. For the new-generation near-space hypersonic vehicles, the flow and heat transfer in the wing-rudder-body interaction region have the characteristics of strong shear and compression simultaneously, resulting in severe local heat flux increment, as a great challenge for thermal protection techniques. A phenomenological decomposition method based on heat transfer mechanisms is proposed, to explain the reason why heat flux is highly increased in these regions. Generalized Rayleigh Flow is established as a theoretical flow model to quantitively illustrate the origin of the heat flux increment. Analytical results for the relative heat flux increment are derived for different angles of attack and the Mach number of freestream. Direct simulation Monte Carlo method is employed to validate the theoretical results. This paper provides a new physical understanding of the aeroheating mechanisms of hypersonic shear-compression flows and is proven to have the potential application value for more complex flows similar to their physical process.

Speaker: Huijun GAO

HiSST 2024 - 204

Interaction of Mainstream Injection with Boundary Layer Combustion for Hydrogen Fuel

Jacob SANDRAL, Tristan VANYAI, Anand VEERARAGAVAN, Vincent WHEATLEY

The University of Queensland (UQ), Australia

Boundary layer combustion (BLC) in scramjet flow paths is often disrupted from strong flow features such as a mainstream injector. Experiments were conducted, investigating the effect a mainstream injector has on boundary layer combustion initiated by a porous plate and multi-porthole injector array (MPIA). Hydrogen was injected at representative flow rates in a 2D ducted flow path to allow for visualization of the flow. High speed schlieren imaging, chemiluminescence and planar laser induced fluorescence measured the flow structure, while thin film heat transfer gauges and pressure gauges characterized the level of combustion. Both the MPIA and porous plate were disrupted along the centerline behind the mainstream injector but were unaffected off axis. The porous plate was able to achieve earlier combustion and had a more uniform layer of fuel.

Speaker: Jacob SANDRAL
Name and Title: Mr. Jacob Sandral
Affiliation and Position: University of Queensland, PhD Student
Education and Degree: Bachelor of Aerospace Engineerin

HiSST 2024 - 069

Analytical Model of Curved-shock Inverse Mach Reflection

Chongguang SHI, Rongguang SU, Tao ZHANG, Chengxiang ZHU, Yancheng YOU

Xiamen University, China

Mach reflection (MR) is an essential component in the development of the shock theory, as well as the transition between regular reflection (RR) and Mach reflection. The hysteresis of Curved-shock reflection (CR) is not yet

adequately understood due to the rotational complexity behind curved shocks. Here, an inverse Mach reflection (InMR), which is possible only in truly unsteady oblique-shock reflection (OR) transition, is found possible to be stable in CR. An analytical model for predicting the stable curved-shock InMR (CInMR) structure is established. Predictions of the Mach stem height and shock structure based on the model exhibit a great agreement with the numerical results. It is found that the compressive waves play a key role in generating the stable CInMR structure.

Speaker: Chongguang SHI
Chongguang Shi, received his PhD degree in School of Aerospace Engineering, in 2021 from Xiamen University and then became an assistant professor in Xiamen University. His research interests include aerodynamic theory, shock wave theory, and boundary layer interaction.

High-Speed Aerodynamics and Aerothermodynamics 5 (HSA 5)

Chairs: Prof. Sang LEE (KAIST, Korea), Dr. Jimmy-John HOSTE (Destinus, Switzerland)

HiSST 2024 - 029

A Boundary Layer Analysis on the HEXAFLY-INT Experimental Flight Test Vehicle

Frederik JACOBS, Johan STEELANT

European Space Agency (ESTEC), Netherlands

As the development of hypersonic flight vehicles is rapidly accelerating, engineers are facing different challenges throughout the design cycle. One of these challenges is the avoidance of hot spots and induced boundary layer transition. Different correlations exist that could be used by designers, but they require specific parameters like boundary layer thickness and edge properties, streamline length, stagnation lines etc… which are not directly provided by a CFD solution. To extract these specific parameters, the Boundary Layer Identification and Transition Zone Detection (BLITZ) code was developed in a previous phase. To further extend the BLITZ tool capabilities and improve its accuracy, a blending methodology between the laminar and turbulent field solution is developed based on an intermittency factor. Together with the implementation of a standalone monitoring property calculation algorithm, it is now possible to make an improved estimate of the total heat load into the vehicle as well as the aerodynamic forces exerted on it considering the evolution of the transitional flow regime. Additionally, improvements on the boundary layer edge detection are presented. A comparison has been made between purely laminar, purely turbulent and transitional flow along the flight trajectory of the HEXAFLY-INT Experimental Flight Test Vehicle regarding boundary layer state, integrated heat load and aerodynamic force. Finally, a first analysis of the effect of the boundary layer state on the weight of the vehicle is provided.

Speaker: Johan STEELANT

Since 1998, he is active at the European Space Research and Technology Centre ESTEC at Noordwijk, the Netherlands where he started first at the structural and thermal sections, and is presently senior expert in the Flight Vehicle and Aerothermodynamics Engineering section. His main interests are advanced vehicle design and numerical simulations of multi-physical phenomena related to conceptual high-speed vehicle design, aerothermodynamics, rocket and airbreathing engines, energy and thermal management.

HiSST 2024 - 083

Compressible Correction and Correlation of γ-Reθ Transition Model for High-speed Flows

Fan YUXIANG, Zhao RUI, Zhang XU

Beijing Institute of Technology (BIT), China

Based on the original γ-Reθ transition model framework, in this work, an improved local correlation-based transition closure model is developed for high-speed flows. The local correlation between the vorticity Reynolds number and the momentum thickness Reynolds number obtained by compressible boundary-layer self-similar solutions, local compressibility correction including the pressure gradient parameter and momentum thickness Reynolds number, and local crossflow correlation are applied to improve the original γ-Reθ model for hypersonic transition predictions. The function Fonset1 used to control the transition onset as well as several relevant model parameters are also modified to make the improved model suitable for high-speed flow. The improved transition model is validated through several basic test cases under a wide range of flow conditions, including high-speed flat plates, sharp cones, HIFiRE-5, and complex hypersonic configuration X-33 vehicles. The numerical results show that the transition onset locations and the changes of heat transfer rate predicted by the present improved

transition model are reasonably consistent with experimental results. The proposed model predicts the high-speed boundary layer transition behaviors induced by streamwise and crossflow instabilities with reasonable precision.

Speaker: Fan YUXIANG

My name is Yuxiang Fan, a second year Ph.D. student from the Beijing Institute of Technology (BIT). My research interests are mainly hypersonic transition model and ablation.

HiSST 2024 - 269

Numerical Study of Turbulent Phenomena in Hypersonic Boundary Layers from the Presence of Protuberances and Cavities

Alan FLINTON[1], Jim MERRIFIELD[1], William IVISON[2], Matthew MCGILVRAY[2], Frederik JACOBS[3], Johan STEELANT[3]

[1]Fluid Gravity Engineering Ltd. (FGE Ltd.), UK
[2]University of Oxford, UK
[3]European Space Agency (EAS-ESTEC), Netherlands

The numerical studies reported here are part of a wider effort to eventually provide a robust and rapid capability for design engineers to take account of turbulent phenomena introduced by gaps and protuberances. Modelling efforts follow two main avenues:

- Navier-Stokes simulations to help set test conditions from experiments, interpret test data and establish the reliability of commonly applied modelling techniques.
- Development of engineering-level methods to directly assist the design process based on the Navier-Stokes simulations and experimental output.

This technical note details numerical rebuilding activities performed on vehicle-relevant wind tunnel experiments at Oxford's High-Density Tunnel (HDT). The effect of each condition on the laminar-to-turbulent transition characteristics on a flat plate setup is simulated along with turbulent heat flux augmentation.

Speaker: Matthew MCGILVRAY

HiSST 2024 - 087

Effects of Aft Angle on the Non-equilibrium Flows over Double Cone at High Enthalpy

Dengke LI, Bo SUN, Chunliang DAI, Xiong CHEN

Nanjing University of Science and Technology (NJUST), China

To understand the effects caused by the different aft angles on non-equilibrium flows over double cone, high enthalpy (21.77MJ/kg) flows over double cones with aft angles of 45°, 50°, 55° and 60° are numerically investigated in the present work. Considering the non-equilibrium effects, the Naiver-Stokes equations coupled with two- temperature model and a seven-species chemical kinetic model are employed to simulate the flow. The enhanced aft angle and the change in shock structures lead to a higher adverse pressure gradient at the vicinity of compressed corner, such that the separation zone extends along both upstream and downstream. In flows of double cone with 45° and 50° aft angle, the shock-shock interactions are close to the Edney type-VI interaction. Whereas, Edney type-IV interaction and secondary separation vortex appear in flow fields of double cone with 55° and 60° aft angle. The strong reaction and thermo non-equilibrium primarily occur just downstream the second cone shock. When aft angle below 55°, the increasing aft angle deepens the degrees of nitrogen dissociation, nitric oxide ionization and thermo non-equilibrium. When aft angle beyond 55°, since the intensity of the strongest part of second cone shock remains unchanged with the increasing aft angle, the degrees of those processes are not sensitive to the aft angle. The increase of aft angle changes the distribution of wall parameters, which are evidenced by a higher maximum wall pressure and wall heat flux in the vicinity of the compressed corner. Overall, the significant differences of flow characteristics are between the flows of 50°and 55°configuration, causing by the transition of shock-shock interaction type.

Speaker: Dengke LI

Li, a doctoral student from Nanjing University of Science and Technology. He is focused on shock/shock interaction and non-equilibrium effect in high speed flow.

HiSST 2024 - 286

Direct Numerical Simulation Study on Pressure Amplification and Shock-boundary Layer Interaction

Yujoo KANG, Sang LEE

Korea Advanced Institute of Science and Technology (KAIST), Korea

In the present study, a direct numerical simulation (DNS) of a shock boundary layer interaction injected with a freestream flow of M = 2.9 over a 24o compression ramp is performed to investigate the increases in the pressure fluctuation. The rise in the pressure is inherent due to the shock compression. However, the increase in the pressure fluctuation is a complex process in which the augmented turbulence plays a dominant role due to the second phase flow deflection. With the lack of understanding at present, the DNS study is an attempt to reveal its pressure amplification mechanism.

Speaker: Yujoo KANG

High-Speed Aerodynamics and Aerothermodynamics 6 (HSA 6)

Chairs: Prof. Chongam KIM (SNU, Korea), Dr. Tamara SOPEK (University of Southern Queensland, Australia)

HiSST 2024 - 256

Hypersonic Flow over the Double Wedge in Low and High Enthalpy Free Stream Conditions

Anurag RAY, Ashoke DE

Indian Institute of Technology Kanpur (IIT Kanpur), India

The present numerical investigation addresses the hypersonic flow over the double-wedge using various gas models exposed to low and high enthalpy free stream conditions. The solver 'hyperKineticFoam' is developed in the finite volume framework, OpenFOAM© environment, capable of simulating the high temperature effects in hypersonic flows representing vibrational and chemical non-equilibrium. This solver utilized in the present numerical investigation to address the impact of different gas models, i.e. thermally perfect gas (TPG) and thermal non-equilibrium with frozen chemistry (TNEQ) on the double wedge configuration by exposing it to the pure Nitrogen with two different free stream conditions. One of the free stream conditions corresponds to the low enthalpy with 2MJ/kg at the inlet, while the high enthalpy represents 8MJ/kg. The preliminary results obtained by comparing the present investigation's data against the experimental results indicate negligible effects of the different gas models on the numerical solution for the low enthalpy case. At the same time, there are minute differences concerning the high enthalpy free stream conditions.

Speaker: Anurag RAY
I am Anurag Ray from the department of aerospace engineering at the Indian Institute of Technology, Kanpur. My current research interests include supersonic and hypersonic flow modelling using Computational Fluid Dynamics

HiSST 2024 - 318

Reduction of Pressure Load and Heat Load by Counter-flow Jet on a Blunt Body in Hypersonic Flow

Min Su HWANG, Hyoung Jin LEE

Inha University, Korea

In hypersonic flow, pressure and heat loads and drag occur due to a shock wave generated in front of an aircraft, and the counter-flow jet was proposed as a technique for pressure load and heat reduction. When the counter-fow jet is injected, Long Penetration Mode(LPM) and Short Penetration Mode(SPM) was observed based on the total pressure ratio of the freestream and counter-flow jet (P0j/P0f, PR). As the PR increased, a recirculation region between the shock wave and the nose of the aircraft is wide, leading to decrease in the pressure, heat load and drag. In this study, reduction of pressure and heat loads and drag caused by the counter-flow jet on a blunt body in hypersonic flow was investigated. The experiment was conducted in the M 7.0 hypersonic shock tunnel. For measuring the heat flux on the surface of the blunt body, in-house K & E type fast response coaxial thermocouple was used. As a result of the experimental, as PR increases, the flow field was changed unstable LPM to a symmetrically stable SPM. In common with LPM and SPM, recirculate zone is generated caused pressure was decreased but there is some place where the pressure locally increases due to the oscillation region of reattachment shock. As a result of simultaneously measuring the temperature by mounting in-house coaxial thermocouple in the blunt body and converting it into a heat flux, no increase measured during test time regardless of LPM and SPM. And increase in a specific region due to the reattachment shock like pressure also

did not measure. The drag reduction is more effective in SPM than in LPM, In the case of LPM, the drag reduction effect was up to 60% compared to when the counter-flow jet was not injected, and in SPM, it decreased by about 79%. As the PR increased, the time when drag affects has been delayed.

Speaker: Min Su HWANG
Min Su Hwang is a master's student at Jet Propulsion Laboratory in Inha university. His research focuses on the hypersonic aerothermodynamics.

HiSST 2024 - 255

Analyzing Convective Heat Transfer over a Blunt Cone across Different Gas Environments

Sreejita BHADURI[1], Naveen KUMAR[1], SLN DESIKAN[2], Mohammed Ibrahim SUGARNO[1], Ashoke DE[1]

[1]Indian Institute of Technology Kanpur (IIT Kanpur), India
[2]Vikram Sarabhai Space Centre (VSSC), India

The present numerical study evaluates the convective heat transfer over a re-entry vehicle. For Mach numbers 16 and 26, the flow has been simulated by considering two different compositions of Mars atmosphere. The study is performed under thermal equilibrium using an in-developed flow solver in OpenFOAM. The investigation examines variations in shock layer flow variables resulting from changes in gaseous composition.

Speaker: Anurag Ray
I am Anurag Ray from the department of aerospace engineering at the Indian Institute of Technology, Kanpur. My current research interests include supersonic and hypersonic flow modelling using Computational Fluid Dynamics

HiSST 2024 - 046

Multi-objective Shape Optimization of Earth Re-Entry Capsule with Aero-Thermal Analysis

Minsul LEE[1], Kyu Hong KIM[1], Hyoungjin KIM[2]

[1]Seoul National Univeristy (SNU), Korea
[2]Kyung Hee University, Korea

In this study, multi-objective shape optimization of the re-entry capsule was conducted by using aerothermal analysis engineering code. Capsule geometry was defined based on three-dimensional axisymmetric Viking geometry having five design parameters. Unstructured triangular surface mesh was automatically generated on surface geometries. The local surface inclination method and reference temperature method were used to estimate surface pressure and the skin friction coefficient. A streamline tracing method was implemented to calculate the local Reynolds number. Stagnation heat flux was estimated using the Brandis formula. Re-entry capsule geometry was optimized in the flow condition of Mach 24.7, angle of attack 0 deg, and altitude 50.63km using a multi-objective evolutionary algorithm, NSGA-III. An optimum solution was selected among Pareto solutions considering the volumetric efficiency, drag area, and heat load as well as mass and ballistic coefficient.

Speaker: Minsul LEE
Minsul Lee is a graduate student at Seoul National University majoring in the Aerospace Engineering Department, South Korea. He is interested in hypersonic aerodynamics.

HiSST 2024 - 302

A Code-to-code Comparison of Turbulent Hypersonic Sharp Cone-flares

Jimmy-John HOSTE[1], Tobias ECKER[2], Chiara AMATO[2], Nicholas GIBBONS[3], Doyle KNIGHT[4], Fahri Erinç HIZIR[5], Tolga KÖKTÜRK[5], Artemii SATTAROV[6], Olivier THIRY[6], Jean-Pierre HICKEY[7], Steven QIANG[8], Jim CODER[8], Neil CASTELINO[9], Valerio VITI[9]

[1]Destinus SA, Switzerland
[2]German Aerospace Center (DLR), Germany
[3]The University of Queensland (UQ), Australia
[4]Rutgers - The State University of New Jersey, USA
[5]Aselsan, Turkey
[6]Cadence Design Systems, Brussels, Belgium
[7]University of Waterloo, Canada
[8]The Pennsylvania State University, USA
[9]ANSYS Inc., USA

As part of the AVT-352 on hypersonic turbulence, a code-to-code comparison has been initiated to evaluate the status of RANS modeling for such flows. To this end, two sharp cone-flare geometries, experimentally studied at CUBRC have been selected for study. Each geometry has been run at various conditions enabling a larger sampling for the various participating CFD codes and turbulence models. The nature of the physics found in cone-flare geometries is known to be extremely challenging for RANS CFD codes. This paper presents an initial status on this endeavor, describing the setups, conditions, and general simulating strategies. Initial simulations confirm the typical overpredictions of pressure and heat flux along the wall after the region of separation.

Speaker: Jimmy-John HOSTE
Jimmy-John is an Aerothermodynamics and Combustion Engineer at Destinus (www.destinus.ch), a Swiss start-up aiming to revolutionize hypersonic cargo transport. His present work targets the design and optimisation of high-speed aerospace vehicle systems based on CFD. Before joining Destinus, he worked as a postdoctoral researcher at CERFACS (2020-2021) and DLR (2018-2020). He completed his PhD in scramjet propulsion at the University of Strathclyde (2014-2018) in collaboration with the University of Queensland following a postgraduate degree in CFD at Cranfield University and an Aeronautical Engineering MSc from the Free University of Brussels.

Propulsion Systems and Components 5 (PSC 5)

Chairs: Prof. Hyunchang LEE (Kyungnam Univ., Korea), Dr. Marc FERRIER (ONERA, France)

HiSST 2024 - 093

Design and Commissioning of TNO's modular Rotating Detonation Engine (RDE) Test Facility

Tim ROOS[1], Wolter WIELING[1], Moana LENGKEEK[2], Martin OLDE[1]

[1] TNO Defense, Safety & Security, Netherlands
[2] Technische Universiteit Delft (TU Delft), Netherlands

Rotating detonation engines are an effective means of utilising detonation combustion in a wide variety of (aerospace) engines. The greater thermodynamic efficiency of detonative combustion, as compared to deflagrative combustion, can be used to fly farther, faster or longer with the same amount of fuel, an attractive prospect in many applications. This work reports on the design of an RDE test facility at TNO in the Netherlands, that was set up to facility research efforts on this promising technology. The results of a commissioning test campaign, which includes what is believed to be the first hot fire of an RDE in the Netherlands, are also presented. The test campaign was conducted using the modular TNO RDC, which is based on a design available in the literature, operating on hydrogen and air. The pressure gain and detonation wave speed measurements obtained in the test campaign are found to compare well to the results available in the literature. Some issues were encountered with the engine diagnostics however, and alternatives to these diagnostics methods will be explored in the future. The air flow rate achieved by the facility is within 5% of the desired value, however the fuel mass flow deviated by as much as 20% from the desired value. This is likely a result of the way the fuel feed line is set up. As experience builds up this variability is expected to decrease, but it will require mitigating measures in the near future. More testing at higher mass flow rates and additional variations in engine geometry is foreseen in the future.

Speaker: Tim ROOS
Dr. Tim Roos is a scientist at TNO Defense, Safety & Security in the Netherlands. He primarily works on supersonic and hypersonic propulsion, as well as aerothermodynamics. His past experience in these topics includes both numerical and experimental work.

HiSST 2024 - 115

Experimental Study on the Propagation Characteristics of Rotating Detonation Engine by JISC Fuel Injector Configuration

In-hoi KOO, Keon-Hyeong LEE, Jeong-Yeol CHOI

Pusan National University (PNU), Korea

In this study, the operation characteristics of the rotating detonation engine (RDE) are confirmed by the shape of the fuel injector that affects the RDE performance. The experiment utilizes a slit-type fuel injector with a 2-dimensional effect and a hole-type fuel injector with a 3-dimensional effect originating from side vortex such as counter-rotating vortex pairs. It is similar to the fuel injection structure of RDE and the transverse jet in supersonic crossflow (JISC). The tendency of the jet penetration affecting the fuel performance was confirmed and quantified. The jet moment ratio of gaseous ethylene injected perpendicularly to the flow of gaseous oxygen was calculated, and the jet penetration height was obtained by using the empirical correlation. The relationship between gaseous ethylene and gaseous oxygen stagnation pressure was derived according to the calculated jet penetration height and RDE channel width. The detonation rate was confirmed by fast Fourier transform (FFT)

analysis, and the hole-type fuel injector showed a 10% higher value than the slit-type fuel injector. In addition, when the hole-type experimental results were compared, it was inferred that there was a correlation between the jet moment ratio and the fuel mixing performance.

Speaker: Keon-Hyeong LEE
I'm a master course in Aerospace Engineering (Rocket propulsion Laboratory). My study topic is Scramjet combustor and RDE experimental research.

HiSST 2024 - 174

Investigation of Wave Behaviour in Non-Premixed H2-Air Annular Rotating Detonation Combustor using Large-Eddy Simulations

Yuxiang LIM, Thommie NILSSON, Christer FUREBY

Lund University, Sweden

A series of Large Eddy Simulation (LES) based investigations was performed to analyse a non-premixed hydrogen-air annular rotating detonation combustor, using a detailed 22-step reaction mechanism and a finite volume based solver previously-designed for high-speed reacting flows. A specific design and test configuration from the US Air Force Research Laboratory has been used. The mass flow rate was maintained at 0.144 kg/s, with a unity global equivalence ratio for the reactant inflows, throughout the simulations. The results obtained from the single stably-rotating wave, showcase the computational model's capability to replicate the principal characteristics of rotating detonation waves. Validation of the numerical results with available experimental data, shows agreement in magnitude and trend. Statistical analysis revealed increased temperature and pressure, volumetric expansion, and fuel suppression during and after the wave sweep, resulting in higher outer wall temperatures in the front axial half of the combustor. The role of reactant mixing in the studied rotating detonation case was also evaluated. Wide ranges of temperature and pressure were observed within the combustor, highlighting the highly dynamic nature of the combustion processes. A significant amount of deflagration was also found to be present in the chamber, with those occurring ahead of the detonation wave having a potentially more significant impact on the combustor performance.

Speaker: Yuxiang LIM
Yuxiang is a third-year PhD student at Lund University, researching on rotating detonation waves via computational fluid dynamics simulations. He graduated in 2014 from Imperial College London, with a M.Eng degree in Mechanical Engineering.

HiSST 2024 - 282

Numerical Investigation of Pulse Detonation Engine with Resonator Injection

Timothee HEMARD, Bayindir H SARACOGLU

von Karman Institute for Fluid Dynamics (VKI), Belgium

Pressure gain combustion (PGC) technology has been heavily investigated by the research community due to its promising theoretical thermal efficiency superiority over constant pressure combustion systems. One of the major implementation of PGC is pulse detonation engines (PDE) whose aeronautical applicability has been proven at the beginning of the millennium. Present research highlighted in this paper aims at investigating the applicability of a PDE with Helmholtz resonator injection system for space thruster applications. In order to investigate the effect of Helmholtz resonator for PDE injection, a thorough numerical study has been performed using the commercial solver Ansys Fluent. Unsteady Reynolds-Averaged Navier-Stokes equations were solved over a detailed computation domain of the entire pulse detonation thruster (PDT) using k-w SST closure and Arrhenius rates for detailed chemical reactions of H2 and O2. Unsteady wave motion on in the resonator and

the mixer prior to the ignition has been recorded at thirteen probe locations and analysed to understand the efficiency of the system to rapidly achieve detonable mixtures in short distances. The current cold flow analysis showed that a detonable mixture can be achieved promptly while the initial hot flow simulations depicted a distinct combustion zone at the mixing region. The full paper will include a detailed analysis of the reactive flow within the PDT at various injection rates. The unsteady features will be investigated in detail both in time and frequency domain. The propulsive performance of the PDT will be analysed at different operating conditions.

Speaker: Bayindir H SARACOGLU
Dr. Saracoglu obtained his BSc and MSc in Mechanical Engineering at Bogazici University, Istanbul in 2004 in 2008, respectively. He graduated from RM Program of VKI in 2008. He completed Wright State University PhD in Engineering Program in Ohio in 2012. He currently works as Research Expert on Propulsion at the VKI. He has expertise in detonation, ramjet/scramjet engines, turbomachinery, flow visualizations and flow control. He has authored more than 80 papers and 2 patents.

HiSST 2024 - 352

Numerical Study on the Characteristics of Detonation Wave Number in RDE

Mohammed N NEJAAMTHEEN, Bu-Kyeng SUNG, Jeong-Yeol CHOI

Pusan National University (PNU), Korea

Detonation engines are likely to be integrated into various aerospace propulsion systems in the forthcoming era. Among the various types of detonation engines being investigated, the rotating detonation engine (RDE) stands out. Despite experimental explorations of the RDE, the intricate mechanism behind the propagation of rotating detonations remains inadequately understood. This work presents a comprehensive study focused on the wave dynamics along with key features of the detonation process and its effects on the flow-field. After reaching a quasi-steady state, the detonation structure in the azimuthal direction is investigated. The high temperature at the detonation front is determined to be around 2800~3100 K. The study investigates the influence of stagnation pressure (p0) and stagnation temperature (T0) on the detonation velocity (UD). Lowering the p0 results in decreased velocities, with the maximum velocity deficit (Udef) occurring at the lowest pressure value. Conversely, increasing p0 leads to a more robust propagation of the detonation wavefront. Similar trends are observed for variations in T0, indicating a weaker wavefront propagation with higher temperatures. The multi-probe study also reveals important details in the detonation front propagation region, the oblique shock wave region, and the combustor chamber exit. The study further explores the time-taken for wave stabilization, finding a correlation between wave number and the required stabilization time. The investigation of pressure peaks indicates an inverse relationship with the number of waves, suggesting significant dynamics influenced by the number of waves present. Beyond a certain threshold, an excessive number of waves can lead to detonation failure. The research findings reveal significant insights into the behavior of the RDE by shedding lights on the wave dynamics, and their implications for the performance and stability of RDE.

Speaker: Mohammed N NEJAAMTHEEN
I am a third-year Ph.D. graduate student pursuing under the guidance of Prof. Choi in Aerospace at Pusan National University, Busan, South Korea. My main focus of research is based on the numerical analysis of the rotating detonation engine and its application in high-speed flows. It also includes combustion and detailed chemical kinetics. This particular research is based on studying the variation in the number of detonation waves and their characteristics on the flow dynamics. This research is very important for the practical applicability of the RDE in the future systems.

Propulsion Systems and Components 6 (PSC 6)

Chairs: Dr. Dermeval CARINHANA JR (IAS, Brazil), Dr. Tristan VANYAI (The University of Queensland, Australia)

HiSST 2024 - 082

Numerical Study on Unstart Characteristics of Scramjet Engine Induced by Fuel Injection

Hyunwoo KIM, Hong-Gye SUNG

Korea Aerospace University (KAU), Korea

In this study, the unstart phenomenon in a scramjet engine triggered by fuel injection was numerically simulated using an in-house code. The analysis domain was set to encompass an intake, isolator, and combustion chamber of a scramjet engine. Flow characteristics within the scramjet's internal flow duct were investigated as the fuel injection increased until unstart occurred. To simulate the dynamic flow characteristics within these internal flow duct, the KW-SST based Hybrid RANS/LES method was applied, incorporating compressibility correction and low Reynolds number correction. Based on the analysis results, the unstart was detected using the CUSUM algorithm. Additionally, the position of the shock train leading edge was quantified by implementing the Pressure Rise Ratio.

Speaker: Hyunwoo KIM
Affiliation and Position: Korea Aerospace University/Graduate student

HiSST 2024 - 222

Experimental Investigation of the Global Equivalence Ratio Influence in a Hydrogen-fueled Supersonic Combustor

Eden Schiavinato de SOUZA[1], Lucas RIBEIRO[1], Leda VIALTA[1], Pedro MATOS[1], Luiz BARRETA[1], Giannino CAMILLO[1], Israel RÊGO[1], Lucas GALEMBECK[1], Dermeval CARINHANA JR[1], Pedro LACAVA[2]

[1]Institute for Advanced Studies (IAS), Brazil
[2]Aeronautical Institute of Technology (ITA), Brazil

The relation between the spatial pressure profile and global equivalence ratio was investigated in a hydrogen-fueled supersonic combustor directly connected to a shock tunnel facility. The combustor model comprises an initial constant area section (isolator), followed by a single-hole fuel injection point, a flame-holder cavity, and finally, an expansion ramp. The results were obtained for a freestream inlet flow at Mach 2.7, static temperature of 705 K, and static pressure of 164 kPa, with stagnation conditions at 1, 470 K and 3.8 MPa. The global equivalence ratio (ER) ranged from 0.10 to 0.50. Dynamic pressure transducers were installed along the combustor model, schlieren images were used to assess the flow profile, and a high-speed OH* chemiluminescence emission technique was employed to verify the occurrence of supersonic hydrogen combustion. Substantial increases in combustion pressures relative to the reference were observed. These increases were in accordance with theoretical predictions for ER ranging from 0.10 to 0.25, showing an increase of 1.5 to 2.3 times the reference pressure. For ER values between 0.25 and 0.50, the pressure increases stabilized at approximately 2.3 times the reference pressure.

Speaker: Dermeval CARINHANA JR
Dermeval Carinhana Júnior is a distinguished researcher at the Institute for Advanced Studies (IEAv), currently serving as the Head of the Technical Sub-directorate. Formerly leading the Division of Aerothermodynamics and Hypersonics, he now oversees the Graduate and Extension Coordination at IEAv. As a Full Professor in the

Aerospace Science and Technology Postgraduate Program at the Aeronautics Institute of Technology (ITA), he contributes significantly to aerospace education. Additionally, he holds the position of Deputy Manager for the "Hypersonic Propulsion 14-X" Strategic Project of the Brazilian Air Force and coordinates the "Flight Test of the Scramjet Technology Demonstrator 14-X S.

HiSST 2024 - 236

Comparative Analysis of Rectangular-to-Elliptical Shape Transition (REST) Intakes with Diverse Leading-Edge Profiles

Daegi YEOM, Hyeonseo LEE, Seongkyun IM

Korea University, Korea

The on- and off-design performances of three rectangular-to-elliptical shape transition (REST) with diverse leading-edge profiles were examined numerically. In the design and analysis of REST intakes, particular attention was given to the notching process, a critical post-processing step that significantly influences the overall flow characteristics and performance of these intakes. The designated Mach number (Ma) for the study was fixed at 7, and all intakes were designed with an approximately 10 contraction ratio (CR), a uniform truncation angle of 3°, and a notching percentage of 2%. The first intake, denoted as Type A, was characterized by a leading-edge shaped according to a sinusoidal function. In contrast, the second and third intakes employed quadratic functions for leading-edge shaping, with convex and concave fitting lines, respectively. Computational fluid dynamics (CFD) simulations were conducted to assess the performance of each REST intake, with a focus on key parameters including total pressure recovery rate, pressure ratio, inlet exit Ma, and captured mass flow rate. The results of this study indicate that the second type of REST intake exhibited notable advantages in achieving a high degree of compression, despite the restricted starting range to Ma 5. Conversely, the third type of REST intake demonstrated the ability to extend the operational range to a lower starting limit of Ma 4.5. These results shed light on the potential benefits and limitations of various leading-edge profiles in REST intakes, thereby contributing to the advancement of intake design for scramjet propulsion systems.

Speaker: Hyeonseo LEE
Graduated from Korea University with a degree in Mechanical Engineering. Focused on research in scramjet inlet design and supersonic combustion for advancements in aerospace technology.

HiSST 2024 - 091

Cavity-based Combustion Characteristics of a Mach 10 Scramjet

Hongbo LU, Hengyi WU, Jian LIN, Ruiting WANG, Feng JI, Xing CHEN

China Academy of Aerospace Aerodynamics (CAAA), China

To promote the efficiency of highly supersonic combustion of high Mach number scramjets, this study highlighted the crucial role of the flame stabilization and heat release enhanced by the cavity-aft shock pattern. A three-dimensional scramjet model was designed, which included a combustor with a constant width and a symmetrical-configured-cavity. The combustion characteristics of the hydrogen jet upstream of the cavity in the highly supersonic crossflow were investigated using OH* chemiluminescence combined with wall pressure measurements at the nominal simulated condition of Ma10 in free-piston driven high enthalpy shock tunnel. The evolution of hydrogen combustion, flame stabilization structure, and heat release characteristics are presented. From the dynamic characteristics of OH* emission, it is found that the so-called “shock tube flow-combustion” mechanism is formed at the immediate moment when the freestream flow entering the scramjet, due to the employment of the fuel injection before the arrival of the mainstream crossflow. This mechanism results in an absolutely different ignition mechanism from the one during the process of fuel injection after the crossflow

absolutely establishes. In spite of this phenomenon, the flame still stabilizes in the bodyside jet wake and the whole flowpath height around the cavity aft under the coupling effect of the self-ignition from the high total temperature and cavity-aft X-type shock pattern when the interaction of fuel jet with the highly supersonic crossflow tends to a quasi-steady regime. The wall pressure rise characteristics induced by heat release reveals that the combustion inside the engine is in a pure supersonic combustion mode, and a maximum heat release rate occurs around the cavity, indicating the combustion is enhanced by the cavity-aft X-type shock pattern. These results of cavity-aft-shock enhanced combustion in a Ma10 supersonic combustor can be aid in design of high-performance combustion for high Mach number scramjets.

Speaker: Hongbo LU

Name and Title: Hongbo LU, Professor, Affiliation and Position: China Academy of Aerospace Aerodynamics, Education and Degree: Doctor, Past Occupation: Engaged in high-speed aerodynamics and supersonic combustion

HiSST 2024 - 114

Study on Equal-Intensity-Distribution Configuration of External-Compression Multi-Wave Curved-Shock Flowfields

Wenguo LUO, Changkai HAO, Jianfeng ZHU, Yancheng YOU

Xiamen University, China

In this paper, based on the computational principle of the inverse method of characteristic, an inverse design method that can specify the compression process of the two-dimensional/axisymmetric captured flow tube is developed for the external-compression multi-wave flowfield of curved surface compression. On this basis, it is proposed that a kind of configuration for curved shock system with the same intensity distribution in the capture height direction. An index parameter named surface compression efficiency ratio is introduced to measure the performance of the equal-intensity-distribution flowfield. The both characteristics of the total pressure recovery and the compression efficiency in the cases of different shock numbers are emphatically studied. In addition, the compression limit of curved shock system is discussed when the initial shock wave is given in different function forms. The results show that the multi-wave flow field with Equal-Intensity-Distribution configuration is actually determined by the initial shock. Enhancing the curved compression characteristics of the initial shock, rather than adding one or two shock waves, could be possible to achieve a total pressure recovery equivalent to or even better than that of the straight shock system, so as to simplify the flowfield wave system. For the initial shock wave in the form of convex function, compared with one end of the focused shocks, the smaller the shock curvature at the other end away from the shock focal point, the higher total pressure recovery that the compression limit could reach.

Speaker: Wenguo LUO

Name and Title: Mr. Wenguo LUO, Affiliation and Position: School of Aerospace Engineering, Xiamen University Education and Degree: Doctoral student.

High-Speed Missions and Vehicles 3 (HSM 3)

Chairs: Dr. Aaron KOCH (DLR, Germany), Dr. Hideyuki TAGUCHI (JAXA, Japan)

HiSST 2024 - 118

Comparison of Different Fidelity Approaches for the Coupled Aerothermodynamic Heating of Hypersonic Reentry Vehicles

Fynn BARZ, Marius FRANZE

German Aerospace Center (DLR), Germany

In the present study the influence of different fidelity flow solvers and structure models on the aerothermodynamic heating of High Lift Reentry Vehicle (HLRV) is investigated. The study is carried out on a generic waverider (WR) geometry. The reference solution is computed by a high-fidelity unsteady RANS coupled multi-disciplinary simulation. The analysis is performed for the forced flight along a reference trajectory. The coupled calculation leads to a realistic evaluation of the overall heating for the vehicle entering the atmosphere of the Earth. The low-fidelity aerodynamic solution is calculated by the Shock-Expansion method. The aerothermodynamic heating is included by the Eckert-Reference Enthalpy method and the Reynolds analogy. The vehicle structure is represented by a one-dimensional heat conduction solver with a simplified material model. The differences between the models of different fidelity are shown.

Speaker: Fynn BARZ
Fynn Barz is a scientific assistant at the German Aerospace Center in the spacecraft department. His research focuses on the multi-fidelity and multi-disciplinary optimization of reentry vehicle.

HiSST 2024 - 189

TSTO Launcher for Small Satellites

Lakshmi Narayana Phaneendra PERI, Francesco MARGANI, Luca ARMANI, Sasi Kiran PALATEERDHAM, Antonella INGENITO

[1] School of Aerospace Engineering University of Rome "La Sapienza", Italy
[2] GAUSS Srl, Italy

A Two Stage to Orbit (TSTO) launcher is engineered to propel small payloads into low Earth orbits by employing the Rocket Based Combined Cycle concept. This innovative approach integrates the technologies of an axi-symmetric cavity-based scramjet combustor and a hybrid rocket in the second and third stages of the launcher. The escalating number of annual launches has created substantial economic pressure. However, the high thrust-to-weight ratio of the Rocket Based Combined Cycle (RBCC) and the reusability of the scramjet offer promising advantages. The proposed design comprises three stages: a solid rocket booster in the first stage, a reusable scramjet in the second stage, and a hybrid rocket in the third stage, enabling the insertion of payloads weighing approximately 100 kgs into orbit. The design and performance of the scramjet inlets play a pivotal role, significantly influencing the overall engine performance. Computational studies have been conducted on the scramjet inlet and combustor, along with an analysis of various performance characteristics of the entire launcher.

Speaker: Antonella INGENITO
Professor of Hybrid Propulsion and New Launch Systems at the School of Aerospace Engineering, Sapienza, University of Rome. Head of the Aerospace Propulsion Laboratory, ASPLab. Since 2006, she has been involved in national and international research projects focusing on hypersonics, particularly in the areas of propulsion, engine and vehicle design, as well as the correlation between ground and flight tests (LAPCAT project). Since 2020, she has been a member of the NATO STO AVT group (Science Technology Organization, Applied Vehicle

Technology Panel) and the International Academy of Astronautics (IAA). Professor Ingenito has authored over 90 international publications and a monograph on ramjet engines.

HiSST 2024 - 374

Overview of the Hypersonic Atmospheric flight KREPE-2

Alexandre MARTIN, Seungyong BAEG, Raghava S.C. DAVULURI

University of Kentucky, USA

The Kentucky Re-entry Universal Payload System (KRUPS) provides a quick-turnaround, low-cost plat- form to conduct atmospheric entry experiments. KRUPS is designed to test multiple types of thermal protection systems (TPS) and scientific instrumentation. Five KRUPS capsules were sent to the In- ternational Space Station (ISS) via the NG-20 Cygnus resupply vehicle. After the completion of the resupply mission, the Cygnus vehicle de-orbited with the capsules inside. Cygnus then broke up into the atmosphere in order to burn up stored trash. These five capsules constitute the second Kentucky Re- entry Payload Experiment (KREPE-2) mission, each with a different heatshield TPS material. Following on the success of the first KREPE mission, the second generation of capsule design added updated avionics, extended battery life, and more scientific instrumentation. Added instrumentation included an updated flight computer, 5 port flushed air data sensing (FADS) pressure port system, GPS receiver, pre-calibrated IMU, and a spectrometer. In addition to this added instrumentation, the KREPE-2 cap- sules can transmit back 5 times more scientific data than the first generation KREPE-1 capsules via the Iridium satellite network. This data will help with the reconstruction of the atmospheric entry environment and validation of computational fluid dynamics (CFD) and material response (MR) models developed at the University of Kentucky.

Speaker: Alexandre MARTIN
Alexandre Martin is the EJ Nutter Professor of Mechanical and Aerospace Engineering at the University of Kentucky in Lexington, Kentucky. His area of research is the modeling of atmospheric entry vehicles, as well as hypersonic flight campaigns.

HiSST 2024 - 088

Comparison of Models for Aerothermal Load Prediction using Coupled Trajectory Simulations of a High Lift Reentry Vehicle

Marius FRANZE, Fynn BARZ

German Aerospace Center (DLR), Germany

This paper uses a high lift reentry vehicle geometry to get unsteady RANS results for aerothermal heating on the out- and inside of the body using the DLR TAU code coupled with a structural solver. The DLR CoNF^{2}aS^2 toolchain (Coupled Numerical Fluid Flight Mechanic And Structure Simulation) is used to perform a coupled Fluid/Structure/Flight-mechanic simulation along the given flight trajectory. From these high-fidelity results in a second step a database along the trajectory is produced, containing the heat flux and temperature distribution on the surface. Afterwards a modified trajectory is calculated and the heating gets interpolated from the database heat flux along the new trajectory and compared with the initial computed flight path. This will speed up the design process of future vehicle geometries regarding TPS and trajectory development.

Speaker: Marius FRANZE
At DLR since 2012 in the field of coupled Fluid-Structure-Flight Mechanic systems for pre and post analysis of flight experiments.

HiSST 2024 - 141

Flyability Assessment and Trajectory Design for a Scramjet Hypersonic Experimental Vehicle

Antonio VITALE[1], Sara DI BENEDETTO[1], Marco MARINI[1], Simone PIZZURRO[2], Roberto BERTACIN[2]

[1]Italian Aerospace Research Centre (CIRA), Italy
[2]Agenzia Spaziale Italiana (ASI), Italy

Flying faster and higher to reduce travel times on long haul routes is one of the main goals of the aerospace research in the last decades. Flight mechanics analyses play a critical role in the development of high-speed vehicles, from their conceptual design till to the flight test execution and post flight studies aimed at the exploitation of experimental data. This paper describes the flight mechanics activities performed in the preliminary design phase of a hypersonic demonstrator, which is based on the waverider concept and equipped with a scramjet air-breathing propulsion system. Its experimental mission envisages an air-launched solution and exploits a launch vehicle to achieve the desired experimental conditions. Specifically, the paper presents and discuss the analyses executed to investigate the hypersonic demonstrator's flyability properties and to define the mission nominal trajectory. The former analyses exploit the aerodynamic database to assess trimmability, manoeuvrability and static stability of the vehicle on the whole flight envelope of interest. Trajectory computation is carried out by solving a constrained nonlinear optimization problem, which takes into account the compliance to the applicable mission requirements and system constraints. Obtained results provide useful information concerning the optimal vehicle configuration and confirm the feasibility of the flight test.

Speaker: Antonio VITALE

Dr. Antonio Vitale works at the Italian Aerospace Research Centre since 2002, where he is currently the head of Flight Dynamics and Simulation Laboratory. Main areas of expertise are mission analysis, handling qualities, modelling and simulation, system identification. He is co-inventor of the award-winning Aspen Evolution Angle of Attack technology, and member of the GARTEUR Group of Responsables for Flight Mechanics

Testing & Evaluation 3 (T&E 3)

Chairs : Dr. Marco MARINI (CIRA, Italy), Dr. Jeroen VANDENEYNDE (ESA, Netherlands)

HiSST 2024 - 090

System Study of an Integrated Facility with Arc-Jet and Expansion Tube for Hypervelocity Testing with Ablating Spacecraft Models

Eric Won Keun CHANG, Tobias A. HERMANN

University of Oxford, UK

Ground testing for the atmospheric entry environment requires precise matching of key flow parameters. However, existing hypersonic facilities can only partially replicate some aspects of this complex environment. Plasma wind tunnels can generate continuous high-enthalpy flow, but challenges arise in achieving aerodynamic similarity. Impulse facilities can match the velocity and total pressure of hypersonic flow, but only for a short test duration. A hybrid facility allows a more comprehensive simulation of atmospheric entry conditions by using the small-scale thermal arc-jet Osney Plasma Generator (OPG) to heat the test model, which is then exposed to the hypervelocity flow generated from the Cold-Driven Expansion Tube (CXT). This paper presents a detailed system design study and discussion regarding the capability of an integrated arc-jet/expansion tube facility.

Speaker: Eric Won Keun CHANG

Dr Eric Won Keun Chang is currently a Postdoctoral Researcher in Hypersonics at the Oxford Thermofluids Institute, University of Oxford. His current research focuses on hypersonic wind tunnel experiments of spacecraft re-entry flows with ablating test models. He completed his PhD in the Centre for Hypersonics at the University of Queensland, where he investigated shock/boundary layer interactions on a preheated model in the T4 free-piston driven shock tunnel. He finished B.S. and M.S. in Aerospace Engineering at KAIST, where he conducted supersonic combustion experiments in a shock tunnel.

HiSST 2024 - 102

Heterodyne Dual Frequency Comb Laser Absorption Spectroscopy Measurements in Supersonic Combustion

Jan MARTINEZ SCHRAMM, Leni SCHMIDT

German Aerospace Center (DLR), Germany

The use of hydrogen combustion based scramjets as propulsion units is one promising possibility to drive hypersonic passenger transport. Although hydrogen-fueled future vehicles do prevent CO2 emission, the formation of NO and H2O during the combustion process may have environmental effects, especially for the atmosphere in the targeted flight altitudes. Therefore, the experimental determination of NO and H2O production in hydrogen combustion is of interest during studies on scramjet models and the corresponding propulsion processes in the High Enthalpy Shock Tunnel Göttingen (HEG). The HEG is a large scale facility of the German Aerospace Center (DLR) and it is operated by the Department Spacecraft of the Institute of Aerodynamics and Flow Technology in Göttingen being one of the major European hypersonic test facilities.

Speaker: Jan MARTINEZ SCHRAMM

- Dr.rer.nat. Physics at University of Göttingen in 2008
- Head of Spacecraft Department Institute of Aerodynamics and Flow Technology since 2021
- Experimental High Temperature Gas Dynamics

HiSST 2024 - 261

Design and Implementation of Electronic Sub-systems for the STAJe- Phase 1 Payload

Sampada Vijay SHELAR, Allan PAULL

The University of Queensland (UQ), Australia

STAJe- Phase 1 is a supersonic flight initiative which uses COTS hardware for the on-board electronic sub-systems and LORA technology is used for tracking of the flight module from an altitude of 20km to ground. The designing and manufacturing of customable printed circuit boards to fit into the mechanical sections of the payload is complete, tested and verified which is an excellent demonstration of interdisciplinary collaboration and rapid manufacturing for space applications. The on-ground testing of the electronic hardware for both, the payload and the telemetry stations, is completed and promising results are summarized. Finally, the conclusion provides a synopsis of different steps involved in the making of a flight vehicle for space applications.

Speaker: Sampada Vijay SHELAR
Ms. Sampada Vijay Shelar has completed her master's in electrical engineering and is currently working as a research officer at the University of Queensland on the STAJe- flight program.

HiSST 2024 - 196

Flow Disturbances at Super-orbital Velocity using Spectral Analysis in Expansion Tube HEK-X

Masahiro FUJIWARA, Keisho ITO, Shun Dylan IZUMA, Honami TOYAMA, Shuto YATSUYANAGI, Hideyuki TANNO

Japan Aerospace Exploration Agency (JAXA), Japan

Disturbances in the test free stream of the free piston-driven expansion tube (HEK-X) were measured at JAXA's Kakuda Space Center as part of the facility calibration. These measurements were made at very high orbital velocities ranging from 8.5 km/s to 11 km/s. A focused laser differential interferometer (FLDI) with high-frequency response characteristics was used to enable measurements with extremely short test times of a few hundred microseconds. The Hayabusa sample return capsule model (20% scaled model) was used as the test model, and density disturbances inside the shock layer near the stagnation point were measured with FLDI and pressure disturbances were measured with a piezoelectric pressure transducer at the model stagnation point, and the frequency characteristics of FLDI and stagnation point pressure were investigated from their time histories. Because the test duration was short (a few hundred microseconds), a spectral analysis method called SWT (Synchrosqueezed Wavelet Transforms) was employed to investigate the time-frequency analysis. This technique allowed both frequency and time to be analyzed with high resolution. A cross-spectrum analysis of the two measurements was also performed. The analysis confirmed that some characteristic frequency mode disturbances appeared after the arrival of the backward expansion wave.

Speaker: Masahiro FUJIWARA
Dr. Masahiro Fujiwara is a research engineer at JAXA. He received his Ph.D. degree from the University of Tokyo in 2023. He contributes to the guidance, navigation, and control aspects of space missions, including the Hayabusa 2 extended mission.

HiSST 2024 - 355

Expansion Tube Capabilities for Studying Boost-Glide Re-entry Conditions

Yuhui LIN[1], James J. WALLINGTON[1], Thien BUI[1], Toby VAN DEN HERIK[1], Christopher M. JAMES[1]
Eric Won Keun CHANG[2], Tobias A. HERMANN[2]

[1]The University of Queensland (UQ), Australia
[2]University of Oxford, UK

The expansion tube is a unique hypersonic impulse facility capable of producing both high-enthalpy and high total pressure conditions simultaneously through the unsteady expansion of a non-stagnated test flow. When coupled with high-performance free-piston or detonation drivers, expansion tubes allow for the simulation of such conditions as scaled Earth re-entry, scaled entry into the atmospheres of other planets in the solar system, and high-speed flight through the Earth's atmosphere. This paper focuses on the latter case and considers the capabilities of expansion tubes for re-creating the conditions experienced at various parts of the re-entry trajectory of a boost-glide vehicle. Boost-glide vehicles are a type of hypersonic vehicle which is boosted into space by a rocket and then 'glides' through the Earth's atmosphere to a target, often re-entering at very high-speeds for flight in the atmosphere of up to Mach 22 (greater than 6 km/s). In a military sense, they are very important strategically and are currently being developed by several nations around the world. The expansion tube's unique ability to simulate high-enthalpy and high total pressure flight makes it particularly well suited to the study of these conditions. This paper will present expansion tube performance envelopes compared to planned boost-glide trajectories and specific facility considerations required to generate these conditions. It will then provide sample experimental data and facility simulations to help quantify the sample conditions.

Speaker: Chris JAMES
Dr Chris James is a UQ Amplify Senior Lecturer at the University of Queensland where he runs UQ's X2 expansion tube facility - an impulse wind tunnel for the simulation of planetary entry and high enthalpy, high-speed flight.

Materials and Structures 3 (M&S 3)

Chairs: Dr. David GLASS (NASA Langley Research Center, USA), Mr. Ilan WEISSBERG (Israel Aerospace Industries, Israel)

HiSST 2024 - 348

Development and Qualification Status of the CMC based TPS of Space Rider

Mario DE STEFANO FUMO[1], Giuseppe RUFOLO[1], Roberto GARDI[1], Roberto FAUCI[1], Angelo DE FENZA[1], Francesca PISANO[1], Giuseppe Maria INFANTE[1], Lorenzo CAVALLI[2], Massimiliano VALLE[2]

[1]Italian Aerospace Research Centre (CIRA), Italy
[2]Petroceramics Spa, Italy

Space Rider is an unmanned space robotic laboratory. After launch it will stay in orbit for about two months and then it will return to Earth with its payloads and land on ground. It can be recovered, reconfigured and reused for up to six missions. Such kind of spacecraft, designed to safely came back to Earth, are characterized by Thermal Protection System (TPS) necessary to protect the vehicle from the typical harsh environment encountered during atmospheric re-entry phase, keeping unchanged the vehicle outer mold line. Further, when precise landing is required, hot control surfaces allowing maneuvers are mandatory. The present paper summarizes the status of the testing activities for the sub-system qualification.

Speaker: Roberto GARDI
Master degree and PhD in aerospace engineering in Naples University. Employed at the Italian Aerospace Research Center since 2005. He has worked on thermal protection systems and materials for atmospheric reentry, including rigid ceramics composite but also flexible TPS for both deployable and inflatable systems.

HiSST 2024 - 233

Optical, Magnetic, and Structural Stability Analysis of PbS Nanoparticles using a Shock Tube

P SIVAPRAKASH, Surendhar SAKTHIVEL, Ki-Won KIM, Ikhyun KIM

Keimyung University, Korea

Developing materials with high stability in such an atmosphere is crucial for meeting the actual needs of practical applications because the majority of functional materials lose their crystallographic sustainability at high temperatures and pressures under shock-loaded conditions. A series of shock pulses with Mach values 2.2 of 100, 200, and 300 have been applied to the PbS nanomaterials with an interval of 5 sec per shock pulse. To investigate the crystallographic, electronic, and magnetic phase stabilities, powder X-ray diffractometers (XRD), diffused reflectance spectroscopy (DRS), and vibrating sample magnetometers (VSM) are used. The material exhibits a rock salt structure (NaCl-type structure), and the XRD indicates that it is monoclinic with the space group C121 (5). Further, the shift was observed as a result of the lattice's contraction and expansion when the material was subjected to shock loading, which indicated the material's stable structure in XRD.

Speaker: P SIVAPRAKASH
Post-Doctoral Fellow, Department of Mechanical Engineering, Keimyung University, Republic of Korea. I have over 50 research publications in reputable journals covering static and dynamic shock wave and materials interactions.

HiSST 2024 - 031

Development of Ultra-High Temperature Ceramic Matrix Composites for Hypersonic Applications via Reactive Melt Infiltration and Mechanical Testing under High Temperature

Luis BAIER, Martin FRIESS, N. Hensch, Vito LEISNER

German Aerospace Center (DLR), Germany

In the ongoing development of hypersonic technologies, material advancements play a key role in meeting the ever-increasing thermomechanical demands of these applications. Ultra-High Temperature Ceramic Matrix Composites (UHTCMCs) offer a promising solution for components operating under such extreme conditions. Their outstanding thermomechanical properties, including high temperature and thermal shock resistance, excellent thermal conductivity and mechanical strength, position them as ideal candidates for applications in fields like leading edges or inlet ramps for ramjets and scramjets. Due to their remarkable composition, UHTCMCs are capable of operating in temperature regimes that surpass 2000K during their operation times under oxidizing atmospheres. At the German Aerospace Center (DLR), a UHTCMC material based on carbon fibres and a zirconium diboride matrix is being developed utilizing Reactive Melt Infiltration (RMI). With RMI, the orientation of the reinforcement fibres can be tailored, to enable the material to fulfill the demanding load requirements. The reactive melt infiltration process comprises three stages: preform fabrication, pyrolysis, and the actual melt infiltration. The foundation for important material properties of the final ceramic, including the matrix composition, is established in the preform production, which is a crucial step in the process. A boron- and zirconium diboride-based slurry is infiltrated into pitched-based carbon fibre fabric. Subsequently, the preforms are consolidated, pyrolysed, and infiltrated with molten Zr2Cu to obtain the UHTC matrix by in situ reaction with the preform elements. Scanning Electron Microscopy (SEM) and Energy-dispersive X-Ray Spectroscopy (EDX) enable examination of the microstructural features, including the arrangement and distribution of zirconium diboride within the matrix. Mechanical evaluation of the UHTCMCs is conducted via 3-point bending tests at both room temperature and at high temperature. It has been demonstrated that Ultra-High Temperature Ceramic Matrix Composites can be produced by means of reactive melt infiltration, and that they retain their strength even at high temperatures.

Speaker: Luis BAIER
Luis Baier M.Sc. Affiliation: Research Assistant & Graduate Student at German Aerospace Center (DLR) Research: Development of Ultra-High Temperature Ceramic Matrix Composites (UHTCMCs)

HiSST 2024 - 055

C/C Material Densification by CVI Process: from Experimental to Simulating Results

J. RAYNAUD[1], Y. QUIRING[2], C. Cairey Remonay[2], G. Borne[1], V. Bontempi[1], E. Schaer[2], R. Fournet[2]

[1]MBDA, France
[2]LRGP, France

R-CVI (rapid chemical vapor infiltration) allows producing ceramic matrix composite material and more specifically carbon/carbon materials with good mechanical properties at high temperature. A numerical simulation model has been developed to understand and improve r-CVI process. The simulation model seems to give good qualitative and to a lesser extent quantitative result in comparison with experimental results. Finally, a parametric simulation study suggests ways of improving the process.

Speaker: Jonathan RAYNAUD
Dr. Jonathan Raynaud is a Chemical Processes Technical Expert at MBDA

HiSST 2024 - 066

Tailored Directional Porosity in Ceramic Matrix Composites (CMC) for Hypersonic Applications

Fiona KESSEL, Martin FRIESS, Carolin RAUH, Alexander WAGNER

German Aerospace Center (DLR), Germany

In the field of hypersonic systems and their missions, the occurring flows impose extreme mechanical and thermal loads on the materials used. At German Aerospace Center (DLR), extensive research is conducted in this area, ranging from design and specification to suitable material developments, and concluding with the proof of concept under realistic conditions in wind tunnels. In recent years, ceramic matrix composites (CMCs) have been investigated for specific aspects of hypersonics. These materials exhibit consistent mechanical behaviour over a wide temperature range (up to 1600 °C), coupled with high damage tolerance and thermal shock resistance, distinguishing them from metals and superalloys. Particularly, special porous C/C-SiC ceramics (carbon-fibre-reinforced carbon with silicon carbide) enable innovative material applications for components in transpiration cooling, fuel injection, or boundary layer transition control. The work presented focuses on the next generation of porous C/C-SiC ceramics currently in development. By deliberately modifying the textile preform, the resulting microstructure and pore morphology are influenced, allowing for control over both the total volume and the orientation of the pores. Relevant parameters influencing porosity have been determined based on the results, and an initial characterization has been conducted. It has been demonstrated that there is a preferred direction of porosity within the sample thickness (Z-axis), and in terms of hypersonic-relevant properties, a supersonic absorption of 0.58 for a frequency of 500 kHz (static pressure of 15 kPa), as well as a length specific flow resistance of 3.4 MPa s/m^2 and an overall porosity of 12.25 % were determined. Building upon these promising initial findings, the goal is to further expand the understanding of the parameters influencing porosity and to generate a tailored material for different application scenarios by correlating them with hypersonic properties.

Speaker: Fiona KESSEL

Affiliation and Position: German Aerospace Center, Department head of the department for ceramic matrix composites, Education and Degree: Master of Science in Textile Engineering, Reutlingen University, Germany

Guidance & Control Systems 1 (GCS 1)

Chairs: Prof. Tao CHAO (Harbin Institute of Technology, China), Ms. Sunayna SINGH (DLR, Germany)

HiSST 2024 - 072

Two Stage to Orbit using a Hypersonic First Stage and Horizontal Launch

Michael PALUSZEK, Christopher GALEA, Stephanie THOMAS

Princeton Satellite Systems (PSS), USA

With the expansion of space commercialization, the need for rapid access to space is increasing. To date, all operational launch vehicles have been vertical launches. Some are reducing costs by recovering and reusing their first stages. Recovery of payloads from orbit is performed using capsules, the same technology that has been used since the Vostok. Space planes, such as the US X-37B and the Chinese space plane are in operation but they are launched by rockets. This paper expands on the authors' past work on the Space Rapid Transit vehicle, a two-stage to-orbit vehicle that takes off horizontally and lands horizontally. The vehicle is sized to carry 500 kg to an ISS orbit and is fully reusable. The first stage is powered by a hydrogen-fueled RDE ramjet with a subsonic rotating detonation combustor. The second stage uses liquid hydrogen and liquid oxygen propellants. The stages separate using their reaction control systems. The new results in this paper cover the control of the two vehicles in the atmosphere and the optimization of the separation Mach number and altitude. The control system transitions from all aerodynamic to mixed reaction and aerodynamic control. The control is partitioned into torque and force demand and actuator (thruster or aerodynamic) and force and torque distribution. This results in a very robust controller. Nonlinear plant inversion is used to implement the core trajectory controller. Control during separation is discussed. An event-based trajectory optimization algorithm is presented. The optimizer selects set points that are implemented by the control system. The resulting two-stage vehicle is demonstrated in numerical simulations. The simulations go from takeoff roll to orbit. The trajectory for the rocket second stage is presented. Future work is discussed.

Speaker: Michael PALUSZEK

Mr. Paluszek is President of Princeton Satellite Systems which he founded in 1992. He works on nuclear fusion, power electronics, spacecraft GN&C and hypersonics. Prior to founding PSS, he worked at GE Astro Space At GE he designed or led the design of several attitude control systems including GPS IIR, Inmarsat 3 and GGS Polar platform. Before joining GE, he worked at the Draper Laboratory and at MIT.

HiSST 2024 - 167

Trajectory Optimization Method for Dual Mode Scramjet Engine Vehicle using a Unstart Informed Combustion Model

Jiwon SON[1], Hyo Sang KO[2], Han-Lim CHOI[2], Kwanjung YEE[1]

[1]Seoul National University (SNU), Korea
[2]Korea Advanced Institute of Science and Technology (KAIST), Korea

Hypersonic air-breathing vehicles, which implement ramjet and scramjet propulsion systems, demonstrate greater specific thrust in comparison to rocket engines. Additionally, these vehicles do not require oxidizers and are thus poised to be the future of hypersonic transportation. The trajectory of hypersonic aircraft plays a crucial function in enhancing flight efficiency because of the inherent connection between combustion efficiency and aerodynamic performance. Therefore, multiple studies have aimed to optimize the trajectory of hypersonic vehicles. Unfortunately, previous studies have not successfully addressed the possibility of disastrous operational breakdowns in the propulsion system, including unstart. In this research, we suggest a trajectory

optimization method for hypersonic aircraft that presents a solution for preventing operational failure. To this end, a comprehensive combustion analysis model was developed and combined with the sequential convex programming to obtain optimal trajectory.

Speaker: Jiwon SON
Jiwon Son is a Ph.D. candidate at Seoul National University, specializing in aircraft design. Jiwon's research focuses on the design of hypersonic airbreathing engine vehicles such as scramjet engine vehicles.

HiSST 2024 - 279

Relative Navigation Implementation for the In-Air Capturing of a Winged Reusable Launch Vehicle

Sunayna SINGH, Briek LUYTEN, Marco SAGLIANO

DLR Institute of Space Systems, Germany

The 'In-Air Capturing (IAC)' return mode is an innovative launcher recovery method that has shown great potential for cost reduction compared to the currently operational reusable launch vehicles (RLVs). This approach, first proposed by DLR, involves capture of a winged rocket stage mid-air using an aircraft, which tows it back to the launch site. This eliminates the need for a supplementary propulsion system for landing and reduces the overall cost of recovery when compared to vertical landing recovery methods, which require significant amount of fuel during descent. For the IAC application, a need for multiple navigation devices have been identified. Both long-range and short-range navigation sensors are required to maintain the relative positions required for IAC. This paper will present the selection and modelling of the navigation solution for full-scale IAC scenario. Sensor integration and overall performance of the system will be studied.

Speaker: Sunayna SINGH
Sunayna received her Masters in Aerospace Engineering from TU Delft, Netherlands. Since 2019, she is working as a research engineer at the DLR Institute of Space Systems, Bremen, Germany. Her research interests include Reusable Launch Vehicles, Flexible Multibody Dynamics, Flight Dynamics, Guidance, Navigation and Control, Re-entry Systems.

HiSST 2024 - 145

Trade Study for the Hardware Design of an AI-Driven Rocket Engine Health Monitoring System: Key Insights and Suggestions

João MATIAS

EDGX, Belgium

In the framework of the Horizon Europe project called "European iNitiative for Low cost, Innovative & Green High Thrust Engine", new technologies are being developed to be applied on future launch vehicles. One focal technology explored is the incorporation of on-board Health Monitoring Systems (HMS) with the inclusion of artificial intelligence (AI) at a propulsion and launcher level for failure detection and identification (FDI) during its entire mission profile. This paper follows the ongoing trade study process performed for the preliminary design of such a rocket engine health monitoring system (EHMS), including the key design considerations and decisions made. Firstly, different aspects of the high-level architecture are discussed, resulting in establishing a distributed heterogenous system where each EHMS unit monitors a single rocket engine. A brief component trade-off analysis concludes that combinations of "commercial off-the-shelf" (COTS) components could be promising candidates for high performance edge AI inferencing within such an EHMS unit. Finally, the challenges associated with performing the study were raised, namely the difficulty in assessing the validity of COTS components for space applications and the lack of test datasets for evaluating space AI applications.

Speaker: João MATIAS
João Matias is the lead Embedded Hardware Engineer for EDGX, a Belgian company specialised in data processing units for AI and Machine Learning applications for spacecraft. He received a master's degree in Aeronautics with Spacecraft Engineering from Imperial College London.

HiSST 2024 - 288

HEXAFLY-INT Actuation System Test Bench Updates

Breno SILVA[1], Pasquale MANZO[2], Carmelo STOLDER[2], Waldemar ROTÄRMEL[3], Johan STEELANT[4], Lucas GALEMBECK[1]

[1]DCTA, IEAV, Brazil
[2]Marotta S.R.L, Italy
[3]DLR e.V., Germany
[4]European Space Agency (EAS-ESTEC), Netherlands

This paper shows the updates done to the test bench of HEXAFLY-INT actuation lane during the last year and the identification of each part contribution on its measurement reliability with the metallic bar. Furthermore, it will present also the Ceramic Matrix Composite (CMC) dummy elevon and torsion bar characterization. Regarding the components to be used in flight test, some alternatives are suggested to perform the aerodynamic load testing using a structure that could simulate a load proportional to the deflection of the elevon.

Speaker: Lucas GALEMBECK
Lucas is an aerospace engineer and helicopter pilot. He worked for 3 years in the HEXAFLY-Int project in close cooperation with ESA, CIRA and many other companies in Italy. Currently, he is the Project Manager of the Brazilian hypersonic vehicle, the 14-X.

POSTER PRESENTATION

PS 01

HiSST 2024 - 172

A Design Method for All-movable Rudder Structure with Lattices and Stiffeners by Thermo-elastic Topology Optimization under Mass Constraints

Yang LI, Tong GAO

Northwestern Polytechnical University (NPU), China

In high-speed vehicles, the all-movable rudder structures are typically subjected to the dual effects of aerodynamic pressure and thermal loads. In this paper, the all-movable rudder structure with lattices and stiffeners is optimized using the thermo-elastic topology optimization method. The main thought of the design method can be summarized as follows: First, the representative lattice units of the selected lattices are equivalent to the virtual homogeneous materials whose effective elastic matrixes are achieved by the energy-based homogenization method. Meanwhile, the stiffeners are modelled using the solid material. Subsequently, the multi-material thermal-elastic topology optimization formulation is established for both the virtual homogeneous materials and solid material to minimize the structural compliance under mass constraint. Thus, the optimal layout of both the lattices and stiffeners could be simultaneously attained by the optimization procedure. Finally, the effectiveness and reliability of the proposed method were verified through the design of a typical all-movable rudder structure.

Speaker: Yang LI

PS 02

HiSST 2024 - 085

Sizing Optimization of Fixed Cross-Section of Combustor in Ramjet Engine for Hypersonic Transport Considering Trajectory

Yingchen LIU, Feng GUO, Jianfeng ZHU, Yancheng YOU

Xiamen Univeristy, China

Based on the Gauss pseudospectral trajectory optimization method, a methodology for aircraft/engine integration of ramjet engine was established. Focusing on ramjet engines operating within a wide speed range (Mach 2.5 - Mach 5), considering the characteristics of aircraft lift-to-drag ratio and flight trajectory, the sizing optimization of fixed cross-section of combustor in ramjet engine was accomplished with the objective of minimizing fuel consumption in the climb phase. The research findings indicate that: An optimal value exists for the cross-sectional size of the ramjet combustor that minimizes fuel consumption during the climb phase. Under the optimal trajectory, with the combustor area at 5.2 m2, fuel consumption is reduced by 208 kg (7.1%) compared to 4 m2 and 200 kg (6.8%) compared to 6 m2 .

Speaker: Yingchen LIU

Affiliation and Position: Xiamen University, School of Aerospace Engineering, PhD Candidate
Education and Degree: Pursuing PhD in Aerospace Engineering, Xiamen University

PS 03

HiSST 2024 - 283

Ignition and Combustion Characteristics of Supersonic Combustor with a Simulation of Altitude Condition

Hojin CHOI, Jong-Ryul BYUN, Sangwook JIN, Jaewon Kim, Dongchang PARK

Agency for Defense Development (ADD), Korea

Ignition and combustion tests of supersonic combustor were conducted with a ground test facility which simulates M4 to M6 flight conditions. In case of ambient pressure conditions at the exit of combustor, many self-ignition and stable combustion cases are shown with gaseous hydrocarbon fuel. To see the effect of separation at the exit of combustor or nozzle where flow is developed to supersonic, altitude is simulated with an air ejector. Many ignition failures and extinction of flame cases took place in the condition where self-ignition and stable combustion were possible with ambient air condition. It was shown that ignition and stable combustion existed due to the ignition source near the separation and interaction with the boundary layer by high-speed imaging and pressure measurement.

Speaker: Hojin CHOI

PS 04

HiSST 2024 - 043

Design and Analysis of Double Design Point Inward-turning Inlet with Osculating Method

Zejun CAI, Xiaogang ZHENG, Waner HU, Zhancang HU, Chengxiang ZHU, Yancheng YOU

Xiamen University, China

The inward-turning hypersonic inlet is pivotal for ensuring optimal incoming flow to the engine, particularly across wide-speed range. However, conventional single design point methods often neglect performance variations across different speeds. To tackle this, a novel Double Design Point (DDP) osculating inward-turning inlet design method is proposed. This method considers mass flow capture under varied flow conditions, offering a comprehensive solution for hypersonic inlet design challenges. High/low Mach design points and mass flow rate are key parameters in DDP design, with the lip streamline crucial for determining mass flow at low Mach points. By integrating these factors, the DDP method effectively addresses hypersonic inlet design challenges. Results indicate that, the DDP basic flow field has excellent agreement with CFD data with less than 1% error. Notably, in osculating inward-turning inlet design, DDP aligns well with the high Mach design point, yielding a mass flow rate of 0.99. However, the influence of 3D effects diminishes mass flow capture at the low Mach design point, the mass flow rate is 0.69 with a design value at 0.80. The main mismatch occurs at the stream trace with a value at 0.53, while the osculating region has a much higher capture ability at 0.75.

Speaker: Zejun CAI

A novel Double Design Point (DDP) osculating inward-turning inlet design method is proposed. This method considers mass flow capture under varied flow conditions, offering a comprehensive solution for hypersonic inlet design challenges. High/low Mach design points and mass flow rate are key parameters in DDP design, with the lip streamline crucial for determining mass flow at low Mach points.

PS 05

HiSST 2024 - 254

A Computational Study on Surface Chemistry of Silane-Coated Aluminum Nanoparticles by Reactive Molecular Dynamics Simulations

Hyung Sub SIM[1], Sungwook HONG[2], Chang-Min YOON[3]

[1]Sejong University, Korea
[2]California State University (CSU), USA
[3]Hanbat National University, Korea

The introduction of high-energetic metal nanoparticles into hydrocarbon-based liquid fuels presents benefits such as increased energy density and improved combustion efficiency. However, the inherent propensity of metal nanoparticles to aggregate poses significant challenges, including diminished energy density and instability in fuel dispersion. To address these issues, our study explores the use of silane coatings on the surface of aluminum nanoparticles (ANPs). Silane precursors are selected for their ability to prevent metal surface corrosion—akin to preventing oxidation on metal surfaces. We utilize molecular dynamics (MD) simulations based on the ReaxFF reactive force field to investigate the silane coating process and to examine the surface characteristics of silane-coated ANPs. The findings reveal that the silane precursor of octadecyltriethoxysilane (OTES) experiences C-O bond dissociation, leading to the formation of an unsaturated O-termination site. This site actively bonds with the surface of the ANPs, creating an Al-O-Si bond, consistent with the experimental observations. In addition, we introduce water molecules to both untreated and silane-coated ANPs to assess differences in surface reactivity. The results indicate that the silane coating layer effectively hinders a direct interaction between the surface of the ANPs and water molecules, potentially imparting hydrophobic characteristics to the metal nanoparticles.

Speaker: Hyung Sub SIM
Affiliation and Position: Assistant Professor in Aerospace Engineering at Sejong University, Seoul, South Korea
Education and Degree: Ph.D. in Mechanical and Nuclear Engineering from Penn State University

PS 06

HiSST 2024 - 210

A Study on Air Plasma Characteristics through LIBS: Spectral Identification and Temperature Estimation

Hari Prasath M[1], Amar GHAR[1], Honhar GUPTA[1], Priyanka CHAVAN[2], Mohammed Ibrahim SUGARNO[1]

[1]Indian Institute of Technology Kanpur (IIT Kanpur), India
[2]National Institute of Technology, Warangal (NIT Warangal), India

Understanding plasma behaviour is crucial for designing effective thermal protection systems that withstand extreme heat generated during hypersonic flight. This work revolves around various techniques to quantify the temperature of air plasma using Atomic Emission Spectroscopy (AES) and discusses some interesting observations. Laser Induced Breakdown Spectroscopy (LIBS) is a technique to produce plasma by focusing a laser pulse to high irradiance. A 532 nm Q-switched Nd: YAG laser with a pulse duration of 10 ns and frequency of 10Hz is focused on atmospheric air to induce plasma at various laser powers of 250-500 mW. The plasma emission was captured by an optical spectrometer. The species present in the spectrum are identified using the NIST Atomic Spectra Database and the temperature of the air plasma at the range of different exposure times varying from 2-14 s are estimated. The results are discussed. The electronic temperature estimated using N II lines in the Boltzmann plot method under the assumption of local thermodynamic equilibrium (LTE) are in the order of approximately 37,000-38,000 K. This is a work in progress and further work will be presented at the conference.

Speaker: Hari Prasath M
My name is Hari Prasath M, an M.Tech. student from the Indian Institute of Technology Kanpur specializing in Aero-Thermodynamics and Thermal Sciences.

PS 07

HiSST 2024 - 238

Numerical Solution of Transpiration Cooling Method in Hypersonic Laminar Flow using the Kinetic Theory Model

Davoud HOSSEINZADEH[1], Esmail LAKZIAN[2,3], Hassan Saad IFIT[4], Ikhyun KIM[1]

[1]Keimyung University, Korea
[2]Hakim Sabzevari University, Iran
[3]Andong National University, Korea
[4]University of Maryland, USA

Transpiration cooling method is proved to be an effective cooling method to diminish the heat flux on the special area of the surfaces of the high-speed vehicles. The cooling process is investigated using nitrogen gas as the coolant and air as the main flow. This study presents a novel approach, as transpiration cooling in hypersonic laminar flow has not been previously simulated through kinetic theory.

Speaker: Davoud HOSSEINZADEH
Mr. Davoud Hosseinzadeh Research assistant, Shockwave and Gas dynamics laboratory, Keimyung University Master's degree in Mechanical Engineering with a specialization in Energy Conversion from Hakim Sabzevari University in Iran Manager of research and development (R&D) unite of Behsaman Energy Rojan Touss Company

PS 08

HiSST 2024 - 073

Development of the Surrogate Model for Combustion of Diesel by Extension of the Naphthene Basis Model

Mehdi ABBASI[1], Ali NATEGHI[1], Saeed HOSSEINI[2]

[1]University of Tehran, Iran
[2]Amirkabir University of Technology, Iran

Diesel fuel is widely used in transportation sections worldwide, such as in road- and railway, as well as in aviation. Despite its importance, the number of existing theoretical studies focused on its combustion characterization, particularly on kinetic surrogate modeling, remained limited. This issue became the topic of recent researches of us. The recently published diesel surrogate model by the authors consists of a semi-detailed kinetic model and three surrogate formulas, including four components, namely: n-dodecane, iso-octane, toluene and cyclohexane, with various mole fractions. As found in previous research, the high-temperature reactions of cyclohexane, as the simplest naphthene molecule available, play important roles in determination of the high-temperature combustion behavior of the surrogate blends. Specifically important were the cascading dehydrogenation reactions of cyclohexane in prediction of ignition delay time data, and formation of the poly aromatic hydrocarbons. Due to this fact, in current research the cyclohexane will be replaced by propyl-cyclohexane, which has more complex molecular structure and larger size, and therefore is known as a more realistic substitution for naphthenic compound found in diesel blends. To this aim, the introduced surrogate formulas will be updated for high temperature ranges, and the corresponding kinetic model will be further extended, using the latest published naphthene sub-model. The simulation results will be compared with the experimental data, namely the high temperature ignition delay time and laminar flame speed data, as well as

with the results of previous model. Since the performance of basis model was very consistent with ignition delay time data, the initial goal of this research is identified as repeating the same model response after substitution of propyl-cyclohexane. On this basis, a new surrogate formula will be introduced. Moreover, the appeared changes in prediction of laminar flame speed data will be in detailed discussed. At the end, the effective pathway toward formation of poly aromatic species will be investigated at the high temperatures.

Speaker: Saeed HOSSEINI
Saeed Hosseini is a PhD candidate at the Amirkabir University of Technology, Tehran, Iran. The field of research is multidisciplinary design, analysis, and optimization of novel civil aircraft.

PS 09
HiSST 2024 - 035

Linear Quadratic Pursuit and Evasion Differential Game Guidance Strategy with Obstacle Avoidance

Xintao WANG, Ming YANG, Ping MA, Tao CHAO

Harbin Institute of Technology, China

In this paper, a class of linear quadratic differential game guidance scheme is presented to study the pursuit and evasion conflict scenario that an evader establishes a static obstacle and performs the evasion maneuver to avoid a pursuer. First of all, the engagement kinematic model among the obstacle, the pursuer, and the evader is linearized according to the assumption. The issue of the pursuit and evasion game is transformed into a linear quadratic differential game through the dead zone and the cost functions. Furthermore, the linear quadratic differential game approach is utilized to obtain the guidance strategy with obstacle avoidance. Numerical simulation results are employed to validate the performance of the guidance policy.

Speaker: Xintao WANG
Xintao Wang is a doctoral student at the School of Aerospace, Harbin Institute of Technology, Heilongjiang, China. His main research directions include hypersonic aircraft penetration game, multi-vehicle collaborative guidance control, aircraft intelligent game, etc.

PS 10
HiSST 2024 - 098

Guidance Law Based on the Sliding Mode Control with Impact Angle Constrained

He DU, Tao CHAO, Ming YANG, Songyan WANG

Harbin Institute of Technology, China

Traditional guidance laws aimed at indirectly intercepting or collide the target are not effective in destroying strategic targets. In this paper, a novel three-dimensional guidance law is proposed based on the sliding mode control with impact angle constraints, which guarantees to intercept the target at a desired angle. In order to meet the realities of combat, the guidance law is based on finite time convergence. The stability issue of the guidance law is theoretically analysed to intercept the manoeuvring target with unknown acceleration at desired impact angle. The stability is also analysed by Lyapunov theory, which ensures that the guidance law can converge to zero in finite time. In order to demonstrate the generality of the proposed method, experiments are conducted in this paper for non-manoeuvring targets, manoeuvring targets with constant acceleration, and weaving manoeuvring targets. Simulation results demonstrate the proposed approach effectively and robustly intercepts the target with impact angle constrained.

Speaker: Tao CHAO
Name and Title: Tao Chao Professor
Affiliation and Position: Control and Simulation Center, National Key Laboratory of Modeling and Simulation for Complex Systems, Harbin Institute of Technology
Education and Degree: Tao Chao received B.S., M.S. and Ph.D. degree from in Harbin Institute of Technology in 2005, 2007, and 2011, respectively.

PS 11

HiSST 2024 - 216

Re-entry Survivability Analysis of Aluminum Oxide with Surface Roughness Considerations

Seong-Hyeon PARK[1], Yosheph YANG[2], Ikhyun KIM[3]

[1]Ecole Polytechnique Fédérale de Lausanne (EPFL), Switzerland
[2]Kangwon National University (KNU), Korea
[3]Keimyung University, Korea

Reentry survivability is important in the minimization of the risk of space object to human populations. An accurate re-entry survivability needs to consider the importance of surface roughness. A preliminary study of re-entry survivability with the surface roughness consideration is carried out based on its effect on the surface heat transfer due to the catalytic properties. Two different levels of surface roughness for aluminum oxide materials are considered in the present study. The catalytic properties of these materials are measured from the heat transfer measurement at the shock tube end-wall combined with the catalytic heat transfer theory. From the experimental measurement, it is found that the catalytic property increases for the roughened material. With the catalytic efficiency values obtained from the experimental condition, the re-entry survivability analysis shows that a material with a high level of surface roughness exhibits a low survivability rate.

Speaker: Ikhyun KIM
Affiliation and Position: Keimyung University / Assistant Professor
Education and Degree:
3. 2016 – 2. 2019 Ph.D., Dept. of Aerospace Engineering, KAIST, Republic of Korea
Dissertation: Experimental Study of Oxygen Catalytic Recombination in a Shock Tube
3. 2014 – 2. 2016 M.S., Dept. of Aerospace Engineering, KAIST, Republic of Korea
Dissertation: Bluntness Effect of Double Compression Ramp in Supersonic Flows
3. 2008 – 2. 2014 B.S., Dept. of Aerospace Engineering, Konkuk University, Republic of Korea

PS 12

HiSST 2024 - 234

Effect of Shock Wave Flows on Ce-BaTiO3 Nanoparticles for Photocatalytic Applications

P. SIVAPRAKASH[1], Surendhar SAKTHIVEL[1,2], S. ARUMUGAM[2], Ikhyun KIM[1]

[1]Keimyung University, Korea
[2]Bharathidasan University, India

In this study, we investigated the synthesis, characterization, and photocatalytic activity of cerium-doped barium titanate (Ce-BaTiO3) nanoparticles (NPs) in the degradation of methyl blue dye under shock impulsion experimentation. Ce-BaTiO3 nanoparticles have been synthesized by using the sol-gel method. Shock wave impulsion experiments were performed on samples 50, 100, and 150 to evaluate the stability of the chemical

and physical properties of Ce-BaTiO3 NPs. X-ray diffraction (XRD) was used to analyses the sample's structural properties. The crystallographic characteristics of the Ce-BaTiO3 NPs were ascertained by performing a Rietveld refinement analysis and confirmed tetragonal structure with good crystalline nature. According to the FESEM investigation, the average grain size of the ambient gradually decreases from 430.02 to 174.75 nm (50 shocks) nm and then drops to 148.19 nm (150 shocks). Our photocatalytic experiment reveals that variables including stress, strain, and bond length have a significant influence on photocatalytic application.

Speaker: Surendhar SAKTHIVEL
Affiliation and Position: Ph.D. student, Department of Mechanical Engineering, Keimyung University
Education and Degree: M.Sc. Physics

PS 13

HiSST 2024 - 032

Three-dimensional Curved Conical Shock Wave/plate Boundary Layer Interactions

Jianrui CHENG, Chongguang SHI, Xiaogang ZHENG, Chengxiang ZHU, Yancheng YOU

Xiamen University, China

In practical aerodynamic scenarios, interactions between curved shock waves and boundary layers exhibiting composite shock curvatures in both streamwise and spanwise directions occur more frequently than those induced by planar oblique shocks. To gain a more systematic understanding of this phenomenon, the three-dimensional curved shock wave/boundary layer interactions (CSBLI) with a curved cone above plate are studied using CFD method with RANS equations. The effects of straight, convex, and concave conical shock waves inducing separation are compared in sections of different directions, reflecting the influence of shock wave on the streamwise and spanwise scales of three-dimensional separation synchronously. Finally, the Mach reflection on both sides of the curved conical shock wave is analyzed by comparing with the inviscid conditions, indicating that the viscous separation bubble can delay the occurrence of Mach reflection.

Speaker: Jianrui CHENG
Affiliation: School of Aerospace Engineering, Xiamen University.
Position: Xiamen, Fujian Province, China.
Education and Degree: Doctoral student.

PS 14

HiSST 2024 - 166

Experimental Study of the Propagation Characteristics of Heated Air-Ethylene Rotating Detonation Wave in a Hollow Combustor

Zhipeng SUN, Yue HUANG, Anjia SONG, sijia GAO

Xiamen University, China

This experimental study discusses the propagation characteristics of rotating detonation waves (RDWs) in a hollow rotating detonation combustor (HRDC) using heated air-ethylene as the working fluid. Through the combination of high-frequency pressure data and high-speed photographic images, a detailed analysis of RDW propagation under high-temperature incoming flow is conducted. Additionally, the effect of equivalence ratio on RDW stability is investigated. Stabilized RDWs were successfully achieved in the experiment at a maximum total air temperature of 711 K. For total air temperatures below 650 K, a wide range of injection equivalence ratios (1.0-1.3) allows for the attainment of stable single-wave modes. Experimental results demonstrate

that under high-temperature incoming flow conditions, RDWs exhibit a significant peak pressure drop while experiencing minimal velocity loss. The color of the RDWs appears lighter and a noticeable deflagration glowing area is observed within the combustion chamber. Various modes of unstable propagation are observed in RDWs, including the coexistence of single-wave and deflagration modes, the coexistence of doublel waves and deflagration modes, as well as rapid switching between single and double waves. In a HRDC, the existence of a central reflow zone along with a substantial amount of deflagration causes fuel loss, resulting in the RDW front equivalence ratio that is frequently lower than the injection equivalence ratio. The stable single-wave mode is primarily achieved under fuel-rich conditions. As the temperature of the air increases, a higher equivalence ratio is required to obtain a stable single-wave mode, and the range of equivalence ratios becomes narrower.

Speaker: SUN Zhipeng

Sun Zhipeng, 26 years old, nationality: China. A PhD candidate at the School of Aeronautics and Astronautics, Xiamen University. Main research interests are rotating detonation combustion and New Advanced Aerospace Propulsion.

PS 15

HiSST 2024 - 173

Theoretical Analysis of Interaction between Rotating Detonation Wave and Upstream Flow Field

Sijia GAO, Han PENG, Yue HUANG, Zhipeng SUN, Yancheng YOU

Xiamen University, China

In order to investigate the interaction between the detonation wave and the upstream airflow, a non-premixed air-breathing rotating detonation combustor with an axial inlet was simulated by using the Navier-Stokes equation of two-dimensional unsteady reaction, a complete structure of rotating detonation wave and upstream flow field was obtained, and the interaction between the detonation wave and the upstream airflow was analyzed by a combination of equation derivation and numerical simulation. The equations for calculating the airflow velocity after the forward shock wave and the height of detonation wave were derived and verified. The results show that the rotating detonation wave would trigger the forward shock wave propagating in the upstream, and the velocity would be weakened and the direction would be deflected of the airflow passing through the forward shock wave. If the airflow velocity drops to a negative value after passing the forward shock wave, there will be no air injection into the combustor. The velocity of the airflow after the forward shock wave is inversely proportional to the velocity of the detonation wave, the temperature of the incoming airflow and the pressure ratio at the forward shock wave. The angle of the forward shock wave is inversely proportional to the velocity of the detonation wave. The interaction between detonation wave and incoming flow is summarized, the higher the intensity of the detonation wave, the slower the recovery time of the airflow after the forward shock wave, and the lower the height of the detonation wave.

Speaker: Sijia GAO

Sijia Gao, who received Bachelor of Engineering degree from Xiamen University in June 2021, and entered Xiamen University in September of the same year to study for a PhD directly under the supervision of Professor Yue Huang. The research interests are detonation combustion and aerospace power systems.

Summary of the research results: Using hydrogen/air as fuel, the three-dimensional numerical calculation of the cold state and combustion of rotating detonation is carried out, and the mixing and operating characteristics of rotating detonation combustors under different injection geometries are discussed. The two-dimensional numerical calculation of kerosene rotating detonation is carried out, the interaction between the detonation wave and incoming flow is obtained, and the calculation model of multiple parameters in rotating detonation flow field is established. The gas phase and two-phase rotating detonation experiments of methane/air and kerosene/air are carried out, and the interaction between detonation wave and wavefront injection was obtained by schlieren optical measurement method.

PS 16

HiSST 2024 - 278

Design and Characterization of a 6-in High-enthalpy Impulse Test Facility

Youngjin JUN, Seongkyun IM

Korea University, Korea

A 6-inch high-enthalpy impulse test facility is constructed at Korea University. Impulse facilities, including an expansion tube, are capable of reproducing a wide range of high-enthalpy gas flows. While impulse facilities are renowned for their mechanical simplicity and cost-effectiveness, they have shorter test times. The primary objective of the expansion tube is to delve into the combustion characteristics of the scramjet combustor. In order to maximize test time, each section's dimensions were meticulously optimized based on analytical solution. Subsequently, numerical simulations were carried out to verify the calculated test durations and conditions and assess the expansion tube's performance. The facility was then constructed in accordance with the design specifications.

Speaker: Youngjin JUN

I earned by Bachelors of Mechanical Engineering from Korea University in 2022. For the past two years, I have been working on my MS course and is about to finish. My research interest is in supersonic combustion and carbonless fuels.

PS 17

HiSST 2024 - 177

Measurement Method of Thermal Environment of Reentry Capsule

Guangsen JIA, Dapeng YAO, Xin JIN, Jian LIN, Nong CHEN

China Academy of Aerospace Aerodynamic (CAAA), China

Accurate prediction of the thermal environment is crucial for the thermal protection design and safe return of the reentry capsule. In order to realize the measurement of temperature-sensitive paint at the bottom of the reentry capsule, the design method of the optical path in the direction of the flow and the correction algorithm of the non-uniform light intensity field were studied. The experimental results show that the embedded positive pressure instrument protection device not only effectively realizes the heat dissipation of the image acquisition equipment and the effective isolation from the vacuum environment, but also realizes the acquisition of temperature-sensitive paint images in the direction of the air flow. The correction algorithm improves the measurement accuracy of temperature sensitive paint under the condition of large angle, and provides an effective experimental method for the measurement of temperature-sensitive paint in the thermal environment of the blunt head.

Speaker: JIA Guangsen

Name and Title: JIA guangsen Senior engineer

Affiliation and Position: China Academy of Aerospace Aerodynamic

Education and Degree: Master of Engineering

PS 18

HiSST 2024 - 359

Study on Modified Crocco's Model for Thermodynamic Calculation for Dual Mode Ramjet Engine

Hyuck Joon NAMKOUNG

Hyundai-Rotem Company, Korea

A pseudo-shock model is proposed, the model makes possible to estimate the distribution of parameters during the transition from a supersonic flow to a subsonic one in the structure of a mathematical model of a supersonic direct-flow propulsion system with deceleration region. A numerical simulation of the gas-dynamic parameters in the channel of the pre-chamber diffuser (isolator) of a given geometry was performed. The numerical solution is obtained using the principle of minimum entropy production. Verification of the proposed model on the data obtained in the course of experimental tests of the combustor of a dual-mode ramjet engine (DMR) has been performed. The model is intended for parametric studies as part of mathematical models of DMR.

Speaker: Hyuck Joon NAMKOUNG

WiPP 01

HiSST 2024 - 376

Subsonic Combustion Test of Dual Mode Scramjet Combustor

Kyungjae LEE, Inyoung YANG, Sanghun LEE, Yangji LEE

Korea Aerospace Research Institute (KARI), Korea

Korea Aerospace Research Institute (KARI) has currently selected a Turbine Based Combined Cycle (TBCC) engine as the engine for hypersonic aircraft and is conducting fundamental research on it. This paper is about the subsonic performance test for the Dual Mode Scramjet (DMS) combustor which is one of the main components of the TBCC engine. The DMS Combustor is equipped with a wall mount type fuel injector and cavity type flame holder for supersonic combustion. In addition, a regenerative cooling type heat exchanger was applied to improve a performance of combustion and wall cooling. Most Ramjet combustors (subsonic combustor) are equipped with exposed type of fuel injector and a v-gutter type flame holder. However, if exposed type fuel injector and flame holder are applied to a supersonic combustor, the air flow may become very complicated due to shock waves caused by exposed parts and internal drag can be increased. Considering various issues, KARI is conducting subsonic performance tests by applying the same type of fuel injector and flame holder as the supersonic combustor. Performance tests were performed by applying various configuration of fuel injector under various combustor inlet temperature. KARI is currently analyzing data to evaluate the effect of changes of the fuel injector configuration and the combustor inlet temperature on subsonic combustion performance, and KARI plan to conduct tests to determine the effect of fuel temperature on subsonic combustion performance in future.

Speaker: Kyungjae LEE

WiPP 02

HiSST 2024 - 379

Plasma-assisted Ignition-stabilized Combustion (PAISC), a Solution Looking for an Application

Ravi PATEL, Nico DAM, Sander NIJDAM, Jeroen VAN OIJEN

Eindhoven University of Technology, the Netherlands

Plasma-assisted combustion (PAC) is a promising technique to ignite and stabilize lean combustion. Over the past few decades, several reports have been published studying the enhancement of weak or unstable flames using non-equilibrium plasmas. However, what if the conditions are such that the flame cannot be stabilized at all, for example, above the blowout limit? To answer this question, we developed a plasma-assisted ignition stabilized combustion (PAISC) strategy to achieve complete combustion at flow speeds much above blowout flow speeds. Pulsed dielectric barrier discharge plasma is used to ignite methane-air flow as it is a fast, repetitive, and energy-efficient ignition source. The main highlight of this work is complete combustion at flow speeds of up to 4 times the blowout flow speed, which costs less than 10 ppm@3%O2 plasma-produced NOx and has a plasma energy consumption of less than 1% of the combustion heat release. We believe that the PAISC strategy will motivate future combustor design with a wider range of operability, especially for high-speed propulsion (Scramjet/Ramjet) engines and gas turbine engines.

Despite huge potential and research efforts from the various groups, plasma-assisted combustion has not reached to market yet, unfortunately. It is a solution that is still looking for an application. We are conducting a market survey to find a problem-solution fit for PAC. This poster presentation aims to inspire discussions on what can be achieved using plasma and its practicality in real-world applications.

Speaker: Ravi PATEL

Ravi Patel received PhD in plasma-assisted combustion in October 2023 from Eindhoven University of Technology, the Netherlands. His areas of interest are aerospace propulsion, combustion, non-thermal plasmas, and optical diagnostics. Currently, he is conducting feasibility study of plasma-assisted combustion in a real-world application.

NOTE

SHORT ABSTRACTS

APRIL 17 WEDNESDAY

ORAL PRESENTATION

High-Speed Aerodynamics and Aerothermodynamics 7 (HSA 7)

Chairs: Dr. Jan MARTINEZ SCHRAMM (DLR, Germany), Dr. Aleksandr FIRSOV (JIHT RAS, Russian Federation)

HiSST 2024 - 057

Heat Transfer Characteristics of the Missile Radome Considering Flight Scenario

Sangbin HAN[1], Hyung Mo BAE[1], Jihyuk KIM[1], Dongkyun LEE[2], Kyeongho LEE[2], Sunghwan YIM[2], Hyung Hee CHO[1]

[1]Yonsei University, Korea
[2]LIGNex1, Korea

The radome of a missile flying at supersonic or hypersonic speeds is subjected to excessive heat flux due to aerodynamic heating, in which kinetic energy is converted into thermal energy in the boundary layer. When the temperature of the radome wall exceeds the material's operating temperature, a critical issue arises as it renders the radome ineffective. Therefore, accounting for aerodynamic heating is crucial in radome design. In reality, the velocity and altitude of a missile change continuously after launch, leading to variations in the heat flux experienced by the radome over time. Therefore, in this study, to ascertain the influence of changing velocity and altitude on radome heat transfer, results of transient numerical analysis assuming the missile cruises at a constant altitude were compared with results of quasi-transient method numerical analysis considering the flight scenario. When considering the flight scenario, significant differences were observed in the temperature of the radome wall, in-depth line, and internal flow. Particularly, when calculating the thermal margin, a deviation of 99.93% was observed compared to the case of cruising at Mach number 7. Thus, this study contributes to understanding radome heat transfer characteristics considering flight scenarios, thereby facilitating stable operation and efficient design of the radome.

Speaker: Sangbin HAN
Han Sangbin is currently a master's student in the HTL Laboratory, Department of Mechanical Engineering, Yonsei University. His research interests include heat transfer and thermal design.

HiSST 2024 - 101

Convective Heat Flux Analysis for a Scramjet Engine

Ana Maria Pereira LARA, Israel REGO, Lucas A. G. Ribeiro, Pedro P. B ARAÚJO, Lucas Galembeck, Dermeval CARINHANA JR , Tiago ROLIM (IAS, Brazil)

Institute for Advanced Studies (IAS), Brazil

The scramjet engine is a hypersonic airbreathing propulsion system based on supersonic combustion. This work investigates the heat fluxes expected in one such engine using analytical approaches. The engine model consists of an inlet composed by a blunt leading-edge region and three compression ramps (compression section), by the combustion and expansion sections. The model is designed to operate at hypersonic speeds in the stratosphere, so it is subjected to high heat transfer loads, specifically on the leading edge. Fay and Riddell's theory, Lees' theory, and Eckert's theory are applied to study the aerodynamic heating at the stagnation point, blunt region, and flat regions of the engine model, respectively. Four models are considered for the determination of the thermodynamic properties and for the calculation of the heat flux, being: calorically perfect gas with and without boundary layer effects, and thermodynamic equilibrium gas with and without boundary layer effects. The highest values of heat flux were found at the stagnation point, followed by a reduction of 96% immediately

downstream of the blunt nose. The greatest increases in the heat flux in the flat regions were due the transition from laminar to turbulent flow regimes, and due to the passage of the flow through the reflected shock wave at the isolator entrance. The lowest heat flux values were found in the flat regions while the flow was still laminar, from the start of the first compression ramp to halfway through the second compression ramp.

Speaker: Dermeval CARINHANA JR
Senior Researcher at the Institute for Advanced Studies, IEAv. Former head of the Aerothermodynamics and Hypersonics Division. Currently, the Head of the Technical Directory of IEAv and Deputy Manager of the brazilian hypersonic vehicle, "14-X".

HiSST 2024 - 142

Separation Studies on Sphere and Cube Clusters in Mach 12 Flow

Dániel Gábor KOVÁCS[1], Guillaume GROSSIR[1], Grigorios DIMITRIADIS[2], Olivier CHAZOT[1]

[1]von Karman Institute for Fluid Dynamics (VKI), Belgium
[2]VKI / University of Liège, Belgium

The present study investigates the aerodynamic separation of compact fragment clusters composed of spheres and cubes. This experimental analysis was conducted in the VKI Longshot hypersonic wind tunnel at Mach 12 flow conditions, using a dual camera free-flight testing methodology. The test articles are initially confined in a sabot, which separates into two pieces and exposes the models to the freestream upon the arrival of the flow. Experiments on clusters of 11 spheres yielded a reasonable agreement regarding the mean terminal velocities with data available in the literature. Increasing the sphere population to 36, yielded greater object spread. Tests on clusters of 11 cubes, which produce a lateral force at most attitudes even individually, demonstrated significantly larger object dispersal, higher lateral terminal velocities, and larger maxima. To draw clear conclusions and to define adequately the separation dynamics on a macroscopic scale, a high number of repeat tests are required, and the problem must be assessed on a statistical basis.

Speaker: Dániel Gábor KOVÁCS
Daniel obtained his MSc in mechanical engineering at the Budapest University of Technology and Economics in Hungary. He has been working at the von Karman Institute since 2018 and is pursuing a Ph.D. in Aerodynamic Investigation of Space Debris Separation.

HiSST 2024 - 140

Assessment of Thermochemical Degradation Effects of Charring Material on the Wall Heat Flux during Atmospheric Re-Entry

Maxime LALANDE, Nicolas DELLINGER, Ysolde PREVEREAUD, Nathalie BARTOLI

ONERA, France

Models providing both quick and reliable estimates of thermochemical degradation effects of charring material on the wall heat flux in hypersonic continuum flow regime are paramount for design activities. In this work, flight point conditions have been extracted from numerous complete trajectory simulations, which are representative of atmospheric re-entry from Low Earth Orbit. High-fidelity simulations are carried out on these flight points to evaluate the influence of pyrolysis gas blowing on wall heat flux modification, with particular attention paid to chemical non-equilibrium effects and outgassed species composition. Additionally, a comparison of two models used to calculate the mixture transport properties is conducted.

Speaker: Maxime LALANDE
Graduated from Ecole Normale Supérieure Paris-Saclay in 2022. Currently Ph.D. student at ONERA The French Aerospace Lab, in Toulouse, France.

HiSST 2024 - 150

The Combined Effects of Large-Scale Roughness and Mass Injection in Hypersonic Flow

Wesley CONDREN, Raghul RAVICHANDRAN, Anthony FINNERTY, Chris HAMBIDGE, Matthew MCGILVRAY

University of Oxford, UK

This paper presents an experimental study into the combined effects of large scale surface roughness and blowing. This represents the transfer of pyrolysis gases through the surface of an ablative. The experiments were conducted in the High Density Tunnel at the University of Oxford where a micro-porous transpiration cooled sample, that has been machined to exhibit an idealised two dimensional roughness pattern at its surface, was subjected to a Mach 5 turbulent boundary layer. Spatially resolved heat transfer data was collected utilising infrared thermography (IRT) adapted to account for the three dimensional effects that result from surface roughness. The heat transfer data was collected at blowing parameters 0-2.5, and molecular weights of 14-28 gmol−1 presented as an augmentation factor relative to the smooth, non injection case.

Speaker: Wesley CONDREN
Born and raised in Bradford in the north of England I started my engineering journey at the University of Oxford achieving my masters and then stayed on to complete a PhD in the combined effects of roughness and blowing in ablative materials at the Thermofluids Institute. I am currently in my 3rd year of study.

High-Speed Aerodynamics and Aerothermodynamics 8 (HSA 8)

Chairs: Dr. Erik TORRES (University of Minnesota, USA), Dr. Tamara SOPEK (University of Southern Queensland, Australia)

HiSST 2024 - 290

Effects of Ultrafast Laser Energy Deposition on a Hypervelocity Boundary Layer

Laurent M. LE PAGE[1], Andrew CERUZZI[1], Thomas L. J. BRAIN[2], Alexander J. RIELEY[2], Tristan J. CRUMPTON[1], James C. ROBSON[2], Matthew ECKOLD[2], Matthew MCGILVRAY[1]

[1]University of Oxford, UK
[2]QinetiQ Limited, UK

This paper presents fundamental study of boundary layer flow phenomena resulting from the energy deposition of an ultrafast laser pulse in proximity to a 7° half-angle axisymmetric cone within the Oxford High Density Tunnel (HDT) facility. An ultrafast Ti:Sapphire laser was integrated into the facility's hardware and software systems providing temporally precise and synchronous delivery of tightly focused single-shot pulses into the HDT test section. This investigation independently assessed the influence of laser pulse durations ranging from 62 to 1000 fs, two beam diameters of 100 and 1000 µm, and laser energies spanning from 1 to 44 mJ on the boundary layer for a nominal test condition at a Mach number of 7.0 and a unit Reynolds number of 12.3 million per metre. With the laser energy source parameters and Mach number held constant, the study also explored effects of changing flow conditions from laminar to turbulent by varying the freestream unit Reynolds number from 5.7 to 24.1 million per metre. For all tests, the boundary layer state was characterised using various diagnostic techniques, including high-speed schlieren imaging (at 1 MHz) for visualising the flow field, focussed laser differential interferometry (FLDI) to assess density fluctuations, and surface-mounted high-frequency bandwidth pressure sensors (PCBs 132A31 and 132B32) for pressure measurements.

Speaker: Laurent LE PAGE
Dr. Laurent Le Page is a Senior Research Associate at the University of Oxford. His work focusses on developing and applying laser-based diagnostics to high-speed flow problems to make quantitative measurements of flow parameters.

HiSST 2024 - 096

Heat Transfer to a Flat Plate under Partially Dissociated Nitrogen Freestream Condition

Guangjing JU, Lin BAO

University of Chinese Academy of Sciences (UCAS), China

This research focuses on the impact of chemical non-equilibrium on heat transfer in high-enthalpy shock tunnel experiments. The rapid acceleration of the expansion flow originating from the high-temperature chamber leads to thermochemical non-equilibrium and incomplete wall catalysis. Consequently, understanding these effects is crucial for accurate heat transfer measurements. Employing computational fluid dynamics, this study investigates the influence of partially catalytic walls on heat flux under high-enthalpy shock tunnel conditions, utilizing a flat plate model. We propose a division of wall heat flux into two components: one governed by classical boundary layer theory, associated with translational-rotational energy, and the other determined by the Damköhler number, linked to catalytic reactions. These findings contribute to developing a methodology for ground-to-flight extrapolation in chemical non-equilibrium hypersonic flows.

Speaker: Guangjing JU
Guanjing Ju is a Master's degree candidate at the University of Chinese Academy of Sciences, specializing in Fluid Mechanics.

HiSST 2024 - 144

Ablation Measurements on Aluminium Spheres in a Hyperballistic Tunnel

Flavien DENIS, Hermann ALBERS, Myriam BASTIDE, Christian REY, Serge GAISSER, Daniel ROTHER, Thierry STEIBLIN

French-German Research Institute of Saint- Louis (ISL), France

This study aims to experimentally measure the ablation of aluminium spheres in hypersonic free flight. The experiment is carried out in the ISL hyperballistic tunnel facility. The 8mm aluminium spheres are accelerated up to 4000m/s and performed a decelerated free-flight in a 21m long tunnel. Several measurements, such as velocity measurements, flash X-ray imaging and high speed imaging are carried out during the free flight to detect and to measure the ablation. In addition, some models are softly recovered for post-flight analysis. The ablation profiles are extracted using an image post-processing algorithm. The results highlight the contribution of the oxidation in the ablation phenomenon and provide experimental results for the validation of the numerical tools.

Speaker: Flavien DENIS
Dr. Flavien Denis is a research scientist in aerothermodynamics at the French-German Research Institute of Saint-Louis (ISL). His research focuses on the heating and ablation of hypersonic projectiles. Since 2022, he has been in charge of the ISL's hyperbalistic tunnel.

HiSST 2024 - 028

Numerical Simulation of the Interaction between a Free-flying Ring and a Curved Shock Wave

Bodo REIMANN

German Aerospace Center (DLR), Germany

A free-flying ring crossing the curved bow shock in front of cylinder was selected as numerical test case within ESA's ATD3 working group in 2022. The experiment to compare with was carried out in the VKI Longshot gun tunnel facility at a free stream Mach number of about 14. This paper presents the DLR simulation results achieved by coupling the DLR in-house CFD solver TAU with a 6-DoF flight mechanic solver. Local dynamic grid adaptation is used to capture shocks and unsteady shock interactions. The results of the coupled simulation are compared to results of a simulation with prescribed motion using the experimental determined motion state as input, and results of a flight mechanic simulation prescribing the measured aerodynamic forces and moments.

Speaker: Bodo REIMANN
Physicist with a PhD in Engineering Research Scientist at the DLR Institute of Aerodynamics and Flow Technology in Göttingen and Braunschweig Main research topics: hypersonics, aerothermodynamics, coupled numerical simulations

Fluid and Heat Transfer Coupled Analysis of a Hypersonic Aircraft with TBCC

Aoto KIKUI[1], Akiko MATSUO[1], Eiji SHIMA[1], Hidemi TAKAHASI[2], Hideyuki TAGUCHI[2], Shunsuke IMAMURA[2]

[1]Keio University, Japan
[2]Japan Aerospace Exploration Agency(JAXA), Japan

This study evaluated thermal effects on a vehicle airframe of a hypersonic aircraft with a turbinebased combined-cycle (TBCC) engine. The purpose of this study is to evaluate the thermal resistance of the airframe by conducting a coupled thermal-fluid analysis of the airframe geometry designed from an aerodynamic point of view. First, a steady-state fluid analysis was performed on the vehicle airframe to confirm the flow field characteristics, such as shock waves generated at the vehicle nose tip. The flow in the upper aircraft was accelerated by expansion waves. In the lower part of the aircraft, compression waves were generated from the engine joints, and a high pressure area was formed over the intake. In the rear of the engine, the flow was accelerated by the expanding nozzle. Second, a coupled fluid/heat transfer analysis was performed on the aircraft. There were temperature vibrations in each case.

Speaker: Aoto KIKUI
Aoto Kikui is a master's student at Keio University, working on thermal performance of hypersonic passenger aircraft using fluid heat transfer coupled analysis.

Propulsion Systems and Components 7 (PSC 7)

Chairs: Prof. Je Ir RYU (New York University Abu Dhabi, UAE), Dr. Jun LIU (NUAA, China)

HiSST 2024 - 287

Numerical Study of Hydrogen Injection in Crossflow to Initiate Oblique Detonation Wave

Ashish VASHISHTHA[1], Rushikesh KORE[1], Sasi Kiran PALATEERDHAM[2], Antonella INGENITO[2]

[1]South East Technological University (SETU), Ireland
[2]Sapienza University of Rome, Italy

The current study is motivated to develop strategies for hydrogen injection in high-speed air stream, at upstream of finite length wedge of oblique detonation wave combustor using numerical simulations. The unsteady two-dimensional Navier-Stokes equations with reactive multi-species along with turbulence modelling are solved for the oblique shock wave (OSW) to oblique detonation wave (ODW) transition for hydrogen injection into high-speed air with wedge at angle θ = 22 0 for incoming air flow velocity of 2400-3400 m/s and pressure of 63 kPa and temperature of 300 K. Initially, premixed hydrogen-air mixture with above freestream speed and pressure and temperature is simulated for given wedge angle to establish oblique detonation wave as reference case. Further, equivalent cases with upstream hydrogen injection (subsonic/supersonic) are simulated with different fuel flow rate to establish shock induced combustion and oblique detonation wave on the finite length 10 cm of wedge length. The transition of oblique shock to oblique detonation wave depends on efficiency of mixing near the vicinity of wedge. The results are discussed with quantification of effective injection length as well as injected mass flow rate to establish the oblique detonation wave.

Speaker: Antonella INGENITO
Professor of Hybrid Propulsion and New Launch Systems at the School of Aerospace Engineering, Sapienza, University of Rome. Head of the Aerospace Propulsion Laboratory, ASPLab. Since 2006, she has been involved in national and international research projects focusing on hypersonics, particularly in the areas of propulsion, engine and vehicle design, as well as the correlation between ground and flight tests (LAPCAT project). Since 2020, she has been a member of the NATO STO AVT group (Science Technology Organization, Applied Vehicle Technology Panel) and the International Academy of Astronautics (IAA). Professor Ingenito has authored over 90 international publications and a monograph on ramjet engines.

HiSST 2024 - 084

Experimental Study of Combustion Modes in PNU-DCSC with a Micro-PDE

Min-Su KIM[1], Keon-Hyeong LEE[1], Eun-Sung LEE[1], Hyung-Seok HAN[1], Seung-Min JEONG[2], Bu-Kyeng SUNG[1], Jeong-Yeol CHOI[1]

[1]Pusan National University (PNU), Korea
[2]Korea Aerospace Research Institute (KARI), Korea

Scramjet engines are critical technologies for air-breathing hypersonic vehicles, with ongoing research aimed at addressing their technical challenges. Supersonic combustion in scramjet engines necessitates rapid fuel-oxidizer mixing and flame stabilization due to the short residence time in the combustor. This study presents findings from experiments conducted using the Pusan National University direct-connect scramjet combustor (PNU-DCSC) integrated with a micro-pulse detonation engine (μPDE). The experimental setup is designed for simulating flight conditions at altitudes of 20~25 km and Mach numbers of 4.0~5.0. The results show that varying the jet-to-freestream momentum flux ratio affects fuel penetration height. Furthermore, as the fuel injection

pressure increases, the combustion area expands, leading to transitions in combustion modes. The flamebase, where peak combustion pressure forms, moves upstream, and pressure oscillations intensify.

Speaker: Keon-Hyeong LEE
I'm a master course in Aerospace Engineering (Rocket propulsion Laboratory). My study topic is Scramjet combustor and RDE experimental research.

HiSST 2024 - 208

Modellings of Steady Shock Reflection with Chemical Heat Release and the Transition Criteria between Regular and Mach Reflections

Haoyang LI[1], Zijian ZHANG[2], Chun WANG[1]

[1] Institute of Mechanics, Chinese Academy of Sciences (IMCAS), China
[2] The Hong Kong Polytechnic University (PolyU), China

This paper presents a pioneering shock-detonation reflection theory and solves the transition criteria to provide a valuable reference for future oblique detonation engine (ODE) design. Initially, we investigate the structure of the oblique detonation wave (ODW) when the deflection angle θ is less than θCJ. We note that the numerical results differ from the theoretical solution predicted by weak underdriven (WU) ODW. When θ < θCJ, a Chapman-Jouguet (CJ) ODW followed by a Prandtl-Meyer isentropic expansion (P-M IE) wave is obtained. In light of this finding, we introduce a CJ + P-M IE theory to reconstruct the relationship between pressure p and θ for the segment of WU detonation polar. Together with the segment of overdriven detonation polar, a whole detonation polar is established. Then, we provide a shock-detonation reflection theory combining the traditional shock polar and the new detonation polar. By analyzing the steady regular reflection (RR) and Mach reflection (MR) structures, we found that the key flow field characteristics, such as the angle of the slip line and reflected ODW, corroborate well with the theory. This verifies the accuracy of shock-detonation reflection theory. Subsequently, we solve the detachment criterion and von Neumann (VN) criterion according to the shock-detonation reflection theory. There are two crucial threshold values: critical heat release QC and critical Mach number MC. When Q < QC, the section of the WU ODW is not employed in the reflection theory. When M < MC, the solution of the VN criterion will be absent. Finally, the transition criteria are verified by numerical simulation under two different heat release Q. The numerical detachment and VN angles are coincident with the theoretical ones. The computations can confirm that the shock-detonation reflection theory and transition criteria are correct in our study.

Speaker: Haoyang LI
I am a PhD candidate (currently studying), and my research direction is shock wave and detonation physics, and detonation instability.

HiSST 2024 - 199

Ignition Delay Study of Liquid Nano-fuels for Application in Pulse Detonation Engines using a Shock Tube

Gagan GARG[1], Viren MENEZES[2], Upendra V BHANDARKAR[2], Bhalchandra P PURANIK[2], Rho Shin MYONG[2]

[1]Gyeongsang National University (GNU), Korea
[2]Indian Institute of Technology Bombay (IIT Bombay)

The ignition delay of various nano-fuels was compared with the base fuel (i.e. aircraft turbine engine fuel) to study the feasibility of use in high-speed aerospace applications (i.e. pulse detonation engines). The base fuel was mixed with two different nano-particles, titanium dioxide (TiO_2) and multi-walled carbon nanotube (MWCNT),

to develop a nano-fuel that can be employed for regenerative cooling of combustor walls before injection. A shock tube was employed to carry out the experiments where the liquid fuel was introduced in the test section as a wall droplet. From the experiments, an increase in the ignition delay was observed for the titanium dioxide nano-fuel whereas a slight reduction in the ignition delay was observed for the MWCNT nano-fuel.

Speaker: Gagan GARG
The presenting author did his doctoral studies at the Indian Institute of Technology Bombay, India, where he developed a hybrid NS-DSMC solver for high-speed rotating flows. Currently, his research interests are developing numerical solvers for non-equilibrium flows.

HiSST 2024 - 036

Effect of Wall Curvature on Detonation Reflection in Combustion Chambers

Hao YAN, Xin HAN, Haochen XIONG, Chongguang SHI, Yancheng YOU

Xiamen University, China

This study investigates the impact of curvature on the reflection of detonation waves in a detonation engine. The reflection of detonation waves in the combustion chamber is inevitable and therefore requires investigation. This paper focuses on the reflection of curved detonation waves on convex and concave walls. It has been determined that there are two mechanisms by which curvature affects the stability of the waves: firstly, curvature affects the angle of the wave, leading to the appearance of a subsonic and high-temperature/high-pressure region behind the wave, which affects stability; secondly, curvature affects the mutual positioning of the wave systems, leading to mutual interference and stability. In addition, analysis of the detonation wave flow field has revealed the important influence of curvature. Therefore, a relationship between the gradient of wave parameters and curvature has been established, which can be used for detonation reflection analysis and generally regulate gradient effects of curved walls. Comparison with simulation results shows that this relationship can effectively predict the gradient of the reflected wave and provide a higher-order analysis tool for detonation reflection.

Speaker: Hao YAN
This study investigates the impact of curvature on the reflection of detonation waves in a detonation engine. The reflection of detonation waves in the combustion chamber is inevitable and therefore requires investigation.

Propulsion Systems and Components 8 (PSC 8)

Chairs: Prof. Hyung Sub SIM (Sejong University, Korea), Dr. Ravi PATEL (Eindhoven University of Technology, Netherlands)

HiSST 2024 - 285

Influence of the Swing Angle on the Performance of Planar SSSL Nozzle

Rui LI, Jinglei XU, Haiyin LV

Nanjing University of Aeronautics and Astronautics (NUAA), China

This study numerically investigates the performance of supersonic splitline nozzles concerning interactions between the airflow and the particles of aluminum trioxide. The existence of the initial arc radius concentrates heavy particles along the axis and scatters light particles to the nozzle transition region. The total length influences the shock wave reflections in the nozzle. The convex diverging profile with a large secondary radius is beneficial for balancing performance parameters. In addition, the swing center upstream of the throat can enlarge the lateral force. Based on these recognitions, the nozzle configuration with an initial arc radius of 10 mm, a total nozzle length of 50 mm, a convex secondary arc of 200 mm, and a swing center at the throat is finally selected to obtain the optimal aerodynamic performance. With the increase in the swing angle from 0 to 6°, the thrust coefficient only drops by 1.89% and always keeps above 0.9356. Meanwhile, its amplification factor exceeds 1.302, and its maximum thrust vector angle is 7.796°.

Speaker: Rui LI
Rui Li comes from China, he is doing post-doctoral research at Nanjing University of Aeronautics and Astronautics. His research interests target the rocket propulsion, combined cycle engine, and the new conceptual engines based on the detonation phenomena.

HiSST 2024 - 252

Computational Parametric Study Evaluating Ramjet Combustor Geometry

David CERANTOLA, Daniel HANDFORD, Pradeep DASS

Space Engine Systems (SES), Canada

Leveraging computational fluid dynamics to design ramjet combustors requires a trade-off between solution fidelity and imposed assumptions. Many previous analyses decoupled the combustor from the adjacent components to increase confidence in the complex chemistry were at the expense of neither capturing flow distortion impact on thrust nor nozzle surface temperatures in excess of material limitations. Given the expectation that a lower fidelity approach can capture bulk flow trends from gaseous-hydrogen and air combustion, the 2D computational domain considered in this paper evaluated both the combustor and converging-diverging nozzle sections with the realizable k-ε turbulence model, two-step reaction mechanism, and turbulence chemistry interactions equated using the eddy dissipation concept. A baseline study that varied flight Mach number (M0) between 3 and 5 and dynamic pressure between 21 kPa and 76 kPa (3–11 psi) showed that specific impulse (Isp) varied between 2400 s and 3600 s as a function of M0 with maximum wall and liner temperatures staying below suggested limits 1300 K and 1770 K respectively. A geometric study that varied injector, flameholder, and liner parameters at M0 = 3 or 5 and 5 psi operating conditions found that performance was most strongly influenced by equivalence ratio φ and liner length L26 where maximizing L26 was beneficial for thrust but L26 < 1 m was required to respect the temperature limits. Setting φ = 0.7 resulted in maximum Isp > 3800 s whereas thrust was maximum when φ = 1.1. The best configuration had no appreciable change in Isp but increased thrust by 41% and 7% at the M0 =3 and 5 conditions respectively relative to the baseline results.

Conclusions identify how the geometric parameters response variability can be leveraged to improve design.

Speaker: David CERANTOLA
David Cerantola is an aerodynamicist at Space Engine Systems and is passionate about applying computational fluid dynamics to industrially relevant problems. He is enthusiastic about participating in the race to achieve hypersonic flight.

HiSST 2024 - 237

Operational Characteristics of a Liquid-fueled Regenerative Dual-mode Combustor Model with Small Inlet Flowpath Height

Inyoung YANG, Sanghun LEE, Kyungjae LEE, Yangji LEE

Korea Aerospace Research Intitute (KARI), Korea

Experimental research was performed for a liquid-fueled regenerative supersonic combustor model. The model features a small inlet flowpath height of 20 mm, which is typical in many scaled experimental research models. Flow speed at model inlet was Mach 2, total pressure was 800 kPa(abs), and total temperature was 1, 290 K which are corresponding to Mach 5 flight condition. The test campaign was done at various fuel flow rate with fixed model geometry and fixed inlet flow condition. Fuel was heated by regenerative heat exchangers before supplied to the injector. The fuel injection condition was varied with various test conditions, in the range of 1.0-2.1 MPa(abs) and 483-493 °C. Transition from scramjet mode to ramjet mode was observed in the model at relatively low fuel equivalence ratio of 0.19. Mode transition at such a low fuel equivalence is addressed to the small inlet flowpath height, by which the effect of boundary layer becomes dominant in the model. The transition was detectable by the wall static pressure distribution, as well as by the direct optical observation of the flame.

Speaker: Inyoung YANG
Dr. Inyoung Yang has been working for Korea Aerospace Research Institute since 1999, after receiving M.S. (1999). He received Ph.D. (2013) with a research on the scramjet engine design and development in Mechanical Engineering from Korea Advanced Institute of Science and Technology. He has been making his career mainly in the field of aeronautical propulsion system, including hypersonic air-breathing engine and gas turbine design and test.

HiSST 2024 - 331

Thrust Enhancement of Rocket-Deployed Dual-Mode Ramjet Engine

Sangwook JIN, Haeseung JEONG, Minchan KWON, Juhyun BAE, Seokjin OH, Hojin CHOI, Jaehoon RYU, Suji LEE

Agency for Defense Development (ADD), Korea

In order to operate an aircraft across a wide range of altitudes and speeds, a combined cycle is required. This combined cycle comprises various engines, each optimized for specific altitude bands. However, in regions where different engines overlap, thrust may become insufficient. To address the issue of inadequate thrust during relatively low-speed, near-hypersonic flight, a dual-mode ramjet combustor with a rocket has been conceptualized. The integrated combustor functions by injecting combustion gases generated by the rocket into the dual-mode ramjet combustor through a strut nozzle. Experimental tests were conducted on the proposed engine to measure the combustor's thrust, which was then compared to thrust values calculated using theoretical formulas.

Speaker: Sangwook JIN

HiSST 2024 - 314

Experiments on High Speed Air-Breathing Propulsion for Sustainable Supersonic Flight

Friedolin Tobias STRAUSS, Konstantin MANASSIS, Marius WILHELM, Christoph KIRCHBERGER

German Aerospace Center (DLR), Germany

This publication will present the results of an ongoing investigation into combustion processes and environmental impacts of ramjets and scramjets at the German Aerospace Center (DLR) within the European MORE&LESS project. It will summarize the first extensive test campaigns within the project with gaseous hydrogen and liquid hydrocarbon-based fuels. In summary more than 100 hot runs have been performed so far in order to generate an emission and combustion data base for validation purposes of CFD simulations and for the simulation of environmental and atmospheric impacts of supersonic flight. An outlook on the results of additional experiments using different types of fuel (e.g. bio fuels) and improved measurement techniques is also presented. Further research requirements and subsequent changes in the test setup are discussed.

Speaker: Christoph KIRCHBERGER
Christoph Kirchberger received a Diploma in aerospace engineering in 2004 and a PhD from Technical University of Munich in 2014 and joined German Aerospace Center afterwards. Since 2020 Christoph is head of the "Satellite and Orbital Propulsion Department" focusing on new energetic materials for rocket and high-speed air breathing propulsion.

High-Speed Missions and Vehicles 4 (HSM 4)

Chairs: Dr. Allan PAULL (The University of Queensland, Australia), Dr. Jeroen VANDENEYNDE (ESA, Netherlands)

HiSST 2024 - 294

e-DEAL Engine for a Mach 0-Mach 5 Cruiser

Francois FALEMPIN

MBDA, France

During the 2000th, MBDA France was developing a large scale engine aiming at demonstrating the ability of a Continuous Detonation Wave Chamber (CDWC) to be integrated to a turbofan to provide up to 15% more fuel efficiency. Nevertheless, harnessing mechanical power from supersonic flows exiting CDWC without substantial aerodynamic losses is very challenging. In that view, MBDA developed with Von Karman Institute and Purdue University a Wavy Bladeless Turbine concept allowing reducing speed of supersonic flow while extracting substantial mechanical energy from it. By another way, MBDA France, in cooperation with the French SME FranceCol, prepared a first demonstration of a turbineless propulsion system using electrical air compression. Taking benefit of this background, the concept of an electrically assisted DEtonation wave Air breathing Liquid fuel engine (e-DEAL) able to power a Mach 5 cruiser is proposed. After a detailed description of eDEAL concept operation, a possible flight demonstration using a small dedicated vehicle is proposed.

Speaker: Francois FALEMPIN
Chief Engineer for Hypersonic programs at MBDA up to 2023. Today Executive Technical Advisor. 14 years at ONERA then 27 years at MBDA

HiSST 2024 - 292

Conceptual Design and Multi-Objective Optimization of an Environmentally-Friendly High-Speed Civil Aircraft

Saeed HOSSEINI, Mohammad Ali VAZIRY-ZANJANY

Amirkabir University of Technology (AUT), Iran

An aircraft design framework is developed and employed for the optimization of a Mach 1.6, 7000 km range, 72-passenger aircraft, to minimize aircraft weight, cost, emission, and noise. To this aim, the aircraft configuration is designed, and a base layout is developed using rapid engineering methods and area ruling requirements. This base layout is then optimized in the developed framework concerning weight, cost, emission, and noise objectives. The core disciplines of the optimization framework are Requirements, Weight, Sizing, Geometry, Aerodynamics, Engine, Performance, Cost, Emission, Noise, and Optimization. High-fidelity CAD and FEA processes are used to loft the aircraft's external surface and estimate the wing weight, respectively.

Speaker: Saeed HOSSEINI
Saeed Hosseini is a PhD candidate at the Amirkabir University of Technology, Tehran, Iran. The field of research is multidisciplinary design, analysis, and optimization of novel civil aircraft.

HiSST 2024 - 322

Achieving Optimal Designs for High-Speed Blunt Body vehicles: A Multi-Objective Approach with an Efficient Aerothermodynamic Prediction Program

Hoonjung YEO, Kyu Hong KIM

Seoul National University (SNU), Korea

In this study, we have developed a rapid thermal aerodynamics analysis program as an alternative to Computational Fluid Dynamics (CFD) for performing fast analyses in the preliminary design step. This program utilizes empirical thermal aerodynamic correlation equations, allowing for efficient computations. We integrated thermal aerodynamics analysis program with a genetic algorithm to provide a design framework for multi-objective shape optimization of high speed vehicles, with objectives including maximizing payload capacity, minimizing total heat absorption, and minimizing ballistic coefficient. For shape optimization, thermal aerodynamic analysis was conducted based on the flow conditions obtained for the baseline configuration's flight trajectory.

Speaker: Hoonjung YEO
PhD. candidate at the Hypersonic&Rarefied Flow research Laboratory, Department of Aerospace Engineering, Seoul National University of Korea Research on thermal analysis of reentry aircraft, capsule

HiSST 2024 - 268

Multidisciplinary Optimization in Conceptual Design of Hypersonic Vehicles

Israel Da Silveira REGO, Ana Maria LARA, Brunno Campos Martins BARBOSA, Thiago ASSUNÇÃO, Lucas Alexandre RIBEIRO, Ronaldo CARDOSO, Tiago ROLIM, Marco Antonio SALA MINUCCI, Lucas GALEMBECK, Dermeval CARINHANA JR, Giannino PONCHIO CAMILLO

Institute for Advanced Studies (IAS), Brazil

The design of hypersonic vehicles and their propulsion systems is complex, which requires knowledge of several engineering disciplines to guide the decisions of their designers. This work presents a multidisciplinary optimization involving aerodynamic efficiency (lift/drag ratio or L/D), longitudinal stability (static margin) and volume in the conceptual design of a hypersonic vehicle of the WAVERIDER class with different horizontal and vertical stabilizers (tail empennage) and fin shapes (clipped-delta and swept ones). Preliminary optimized solutions show that WAVERIDER vehicles with conventional tail empennage featuring three swept fins are preferable in terms of aerodynamic performance and flight control feasibility under volume restrictions.

Speaker: Lucas GALEMBECK
Lucas is an aerospace engineer and helicopter pilot. He worked for 3 years in the HEXAFLY-Int project in close cooperation with ESA, CIRA and many other companies in Italy. Currently, he is the Project Manager of the Brazilian hypersonic vehicle, the 14-X.

HiSST 2024 - 339

Preliminary Design of the Flight Control System for a Mach 5 Hypersonic Civil Passenger Aircraft

Oscar GORI, Simona LOCCISANO, Davide FERRETTO, Nicole VIOLA

Politecnico di Torino, Italy

The Flight Control System (FCS) plays a crucial role in enabling the maneuverability and stability of the aircraft

across a wide range of flight conditions. It is of utmost importance to consider the FCS during the initial stages of a project, particularly when designing high-speed vehicles, where the impact of control surfaces deflections on the aerodynamic performance may be significant. Additionally, ensuring high-speed aircrafts' manoeuvrability and stability while meeting required standards presents a greater challenge compared to conventional subsonic aircraft. This paper addresses the preliminary design of the flight control system for a hypersonic aircraft: the STRATOFLY MR5, a Mach 5 civil passenger vehicle developed within the H2020 MORE&LESS project. The steps followed in the preliminary design of the flight control system are reported. Initially, the geometric definition of all control surfaces is presented, followed by an estimation of potential deflections required to achieve vehicle's stability and trim along the different flight regimes.

Seaker: Oscar GORI
Oscar Gori gratuated in 2019 in Aerospace Engineering at Politecnico di Torino, Italy. He is currently a PhD student at Politecnico di Torino, focusing on high-speed vehicle design and mission simulation.

Propulsion Systems and Components 9 (PSC 9)

Chairs: Dr. Tristan VANYAI (The University of Queensland, Australia), Prof. Hyunchang LEE (Kyungnam University, Korea)

HiSST 2024 - 117

Progress in the Development of a TPaSR Model for the Simulation of Combustion in Turbulent Supersonic Flows

Margot PRUVOST[1], Marc FERRIER[1], Arnaud MURA[2]

[1] ONERA, France
[2] ENSMA, France

Simulating turbulent combustion in supersonic flows is a challenging yet essential task in designing scramjet combustors. In the high Reynolds number flows passing through the combustion chamber, mixing and chemical time scales have the same order of magnitude. Because of turbulence intermittency, dissipative structures are non-homogeneously distributed, leading to incomplete mixing of chemical species at the molecular level. In order to take into account this uneven distribution of the micro-mixed volumes in turbulent combustion simulations, Partially-Stirred-Reactor (PaSR)-like models have been developed. They assume that each computational cell is composed of a well-mixed region and its surroundings. However, considering a local model to describe the mixing process is a strong assumption since it does not take into account the whole history of micro-mixing. Furthermore, the chemical and mixing time scales are key parameters in these models and their estimation becomes challenging when dealing with complex configurations such as scramjet combustion chambers. In this paper, we introduce a new approach for the simulation of turbulent combustion and present its ongoing development. It is based on the PaSR concept together with a multi-fluid framework. In the computational domain, two fluids are considered: one relevant to the well-mixed volumes, and the other acting as their surroundings. Two sets of transport equations are considered to describe them. Within this Transported PaSR (TPaSR) framework, species micro-mixing and thermal diffusion are represented by source terms transferring mass and energy between the two fluids. In this study, expressions for mass and energy transfer are proposed and the model robustness is assessed on the NASA Langley Research Center supersonic coflowing burner. The model reproduces the regions within the mixing layer between fuel and oxidizer streams, and ensures mass transfer from one fluid to another at a higher rate in these regions.

Speaker: Margot PRUVOST
I am currently a 3rd year PhD student at ONERA (France), in the field of turbulent combustion modeling. Prior to this, I obtained a Master of Engineering in Energetics and Propulsion from INSA Rouen Normandie.

HiSST 2024 - 080

Numerical Investigation of Shock Induced Mixing Enhancement in Cavity-Based Scramjet Combustor

Tomoaki NARA, Chihiro FUJIO, Hideaki OGAWA

Kyushu University, Japan

In this study, the characteristics of fuel mixing due to shock wave interaction in a transverse injection cavity-based combustor are investigated, with a focus on performance and flowfield. The performance and flowfield are evaluated by injecting oblique shock waves at various locations for a specific cavity geometry. Computational Fluid Dynamics (CFD) simulations using the RANS SST k-ω model is conducted to obtain the flowfield. As a result, it is verified that the mixing efficiency is improved when the shock wave is incident on the cavity. It is also found

that the mixing efficiency is most improved when the shock wave interacts with the rear edge of the cavity. In addition, assuming shock wave interaction, the drag is lowest at the location where the shock wave also interacts with the rear end of the cavity.

Speaker: Tomoaki NARA
Mr. Tomoaki Nara is a graduate student in the Department of Aerospace Engineering at Kyushu University in Japan. He conducts analyses using CFD, focusing on scramjet combustors.

HiSST 2024 - 334

Nitrogen Oxides Emission Estimation for a Hydrogen-fuelled Dual-Mode Ramjet in the Conceptual Design Phase

Valeria BORIO[1], Roberta FUSARO[1], Nicole VIOLA[1], Guido SACCONE[2],Ginevra CIANCI[1]

[1] Politecnico di Torino, Italy
[2] Centro Italiano Ricerche Aerospaziali (CIRA), Italy

This paper aims to investigate the P3-T3 method originally developed for nitrogen oxide emissions estimation of subsonic kerosene-fuelled aircraft and to extend its applicability to an unconventional high-speed propulsive system and to hydrogen fuelling. For this purpose, the introduction of two new variables, namely the Mach number and the Damköhler number, proves to extend the applicability of the analytical formulation up to Mach 8. The new formulation is developed thanks to the availability of 1D chemical-kinetic simulations of the combustor of the Dual-Mode Ramjet engine installed onboard the STRATOFLY MR3 vehicle, a hypersonic civil transportation vehicle with a waverider configuration. Moreover, in an effort to verify the independence of the novel P3-T3 formulation from the reference emissive database, the DLR-Stöppler formulation was considered. The upgrade of the P3-T3 method allows the mean estimation error to be reduced from 17.28%, resulting from the original formulation, to 0.399% of the novel formulation. The updated DLR-Stöppler method provided nitrogen oxide emissions assessments with a mean error of 0.405%, comparable with those of the novel P3-T3 method.

Speaker: Valeria BORIO
Valeria Borio is a Ph.D. student in Aerospace Engineering at Politecnico di Torino supervised by Professor N. Viola and Dr. R. Fusaro (POLITO), and Dr. G. Rufolo (CIRA). Her research focuses on the development of sustainable space transportation systems.

HiSST 2024 - 070

Investigation on Multi-channel Gliding Arc Plasma Enhanced Supersonic Ignition at Near Blowout Limit

Tiangang LUO, Jiajian ZHU, Mingbo SUN, Yifu TIAN, Minggang WAN, Yongchao SUN

National University of Defense Technology (NUDT), China

The ignition enhancement process of liquid kerosene at room temperature in a scramjet combustor by multi-channel gliding arc (MCGA) plasma was carried out under a Mach number of 2.5, a total temperature of 1600 K, and a total pressure of 1.65 MPa. The CH* images of the flame were synchronously captured by two high-speed cameras with a 20 kHz frame rate on the side and top of the combustor, and the schlieren images were captured on the side of the combustor with the same frame rate. The current and voltage waveforms of MCGA plasma discharge were simultaneously recorded with cameras. The flame kernel is formed at the discharge power peak of the MCGA plasma. The continuous discharge of MCGA plasma can generate multiple flame kernels. The merge of flame kernels contributes to the development of flame and the establishment of global flame. The ignition process of MCGA consists of three stages: flame kernel formation stage, flame propagation stage, and flame self-

sustaining stage. MCGA plasma can provide repeatable enhanced ignition of kerosene within the GER range of 0.24 to 0.46. It can also maintain flame and enhance ignition near the lean blowout limit.

Speaker: Tiangang LUO
Tiangang luo, a doctoral student from National University of Defense Technology.

HiSST 2024 - 153

Development of an Empirical Correlation for Ethanol Jet in Crossflow Spray Profiles in Transonic and Supersonic Flows

Aubrey MCKELVY[1], James BRAUN[1], Guillermo PANIAGUA-PEREZ[1], Etienne CHOQUET[2], Thierry ANDRÉ[2], François FALEMPIN[2]

[1] Purdue University, USA
[2] MBDA, France

Liquid Jet in Supersonic Crossflow and Subsonic Crossflow are used in various industrial, automotive, and aerospace processes as a mixing strategy. For high momentum crossflows, plain orifice injectors are preferred to atomizing injectors because significant penetration of the liquid jet and subsequent mixing requires the injectant to have a substantial momentum flux compared to the crossflow. The complexity of two-phase interactions in the atomization process has resulted in the use of empirical correlations for the determination of spray features relevant to engine designers. This paper details the development of a correlation for liquid ethanol spray penetration from a plain-orifice injector with experimental validity across both the transonic and supersonic crossflow regimes.
Penetration heights and spray transmittance are measured in a 23x117x54 cm linear test section with 2crossflow Mach numbers ranging from 0.3 to 0.8. Contoured 2D converging-diverging nozzles are inserted into the bottom of the test section to produce supersonic flow with both a conically expanding and a bellshaped flow path providing Mach numbers of 2 and 3, respectively, at the injector. A novel mapping procedure is used to compare penetration heights between differing flow fields, and an analytical derivation for a momentum flux correction factor is used to collapse penetration heights across both the subsonic and supersonic regimes. The correlation utilizes a logarithmic function to account for both near-field (x/d 0-50) and far-field (x/d 50-200) spray patterns that power-law correlations fail to capture. The performance of the correlation is finally compared to a selection of published correlations that are valid for similar flow conditions.

Speaker: Aubrey MCKELVY
Aubrey McKelvy is a third year PhD candidate working under Professor Guillermo Paniagua at the Purdue Experimental Turbine Aerothermal Laboratory (PETAL) at Purdue University. He conducts experimental research on liquid jets in crossflows.

Materials and Structures 4 (M&S 4)

Chairs: Dr. Abhendra SINGH (Baylor University, USA), Mr. Yann QUIRING (CNRS, France)

HiSST 2024 - 040

A Multiscale Framework for Aero-thermo-chemical DFT/CFD Simulation for Re-entry Environment

Jongkyung AN, Seunghwan KWON, Jiseon AHN, Rajkamal ANAND, Gun Jin YUN

Seoul National Univeristy (SNU), Korea

Ultra High-Temperature Ceramics (UHTC) are being developed as surface materials for re-entry vehicles in Low Earth Orbit (LEO) environments due to their resilience to the effects of atomic oxygen(AO). However, evaluating the performance of UHTC ceramic materials through experiments consumes a significant amount of time and resources. To address this, we have developed a DFT/CFD multiscale framework for the re-entry performance assessment of heat shield materials. This framework verifies the use of DFT properties as input parameters for CFD analysis by comparing DFT properties and experimental data, enabling the evaluation of thermal and mechanical performance of re-entry vehicles for which heat shielding materials are used.

Speaker: Jong-Kyung AN
Seoul national universtiy, Department of aerospace engineering, Ph.D student

HiSST 2024 - 281

Modelling, Simulation and Testing of Inflatable Structures Applied to Re-entry in the EFESTO-2 Project

Roberto GARDI[1], Barbara TISEO[1], Gianluca DIODATI[1], A. SORRENTINO[1], Vincenzo QUARANTA[1], Cedric JULIEN[2], Giuseppe GUIDOTTI[3], Giuseppe GOVERNALE[4], Francesco PUNZO[5], Pietro PASOLINI[6], Maxim DE JONG[7]

[1]Centro Italiano Ricerche Aerospaziali (CIRA), Italy
[2]ONERA, France
[3]Deimos Space S.L.U, Spain
[4]Politecnico di Torino, Italy
[5]Aerospace Laboratory for Innovative components S.p.a (ALI), Italy
[6]SRS Engineering Design s.r.l., Italy
[7]Thin Red Line Aerospace (TRLA), Canada

Inflatable Heat Shields (IHS) are poised to revolutionize space travel, enabling missions that prioritize both increased payload capacity for scientific instruments and resources, and reusable spacecraft for sustainable exploration. However, unlocking this potential requires maturing key technologies. This is precisely the focus of the European projects EFESTO and EFESTO-2, funded respectively by H2020 (grant nr. 821801) and HORIZON EUROPE (grant nr. 1010811041). EFESTO, attempted the initial challenges of developing the core elements of IHS: the inflatable structure and flexible thermal protection system. This project significantly advanced the Technology Readiness Level (TRL) of these components. Building upon this foundation, EFESTO-2 focused on consolidating critical technical aspects and adopting a broader system engineering perspective. In particular, the EFESTO-2 project focused on implementation of a sound testing effort to improve knowledge of this peculiar systems with respect to the topics of aero-shape and structure. A Fluid Structure Interaction (FSI) investigation was executed to retrieve deformation of the inflatable structure under aero-loads and then understand impact of shape deformation on both aerodynamic drag and aerothermal loads, by means of CFD and wind-tunnel tests. The structural and mechanical characterizing was appointed through numerical modelling and analysis first, then with extensive testing of a meaningful-size ground demonstrator of the inflatable structure, and then again with cross—correlation of test data with FEM results. This paper focuses on two of the many activities carried on in the frame of the project: The FSI and the dynamic characterization. A dedicated effort has been also made to model and simulate morphing behavior of the inflatable structure during folding and unfolding, aimed to reproduce the actual folding process.

Speaker: Roberto GARDI
Roberto Gardi PhD is a System Engineer of the CIRA Italian Aerospace Research Center. He got his master's degree and PhD in Aerospace Engineering.

HiSST 2024 - 064

CMCs for Missile Applications: Elaboration and NDI of EBCs at an Industrial Scale

Jonathan RAYNAUD, Maxime LHUISSIER, Magali ROLLIN

MBDA, France

Ceramic matrix composites (CMCs) are used in high temperature applications, for example for aircraft brakes or rocket nozzles. In recent years, this kind of materials is of more and more interest for the development of missile parts subjected to temperatures above 400 °C.
To guarantee their performances, some CMCs require to be protected by an environmental barrier coating (EBC). Despite their low thickness which do not exceed a few hundred microns, an EBC has to avoid air penetration in the CMC structure. So, it has to contain a minimum amount of microcracks and pores. Firstly, this needs an adapted elaboration process, robust whatever the dimensions and the shape of the parts. Secondly, this needs control methods able to visualize the microstructure non-destructively with a sufficient resolution.
EBCs have been elaborated at the surface of a C/C plate by several technics using the same principle: application of a slurry, drying and heating. These technics are Liquid Silicium Infiltration (LSI) and Polymer Derived Ceramic (PDC). Some process parameters have been studied to know their influence on the EBC microstructure: CMC surface roughness, slurry coating thickness, heat treatment. The obtained samples have been observed by microscopy and by microtomography. In parallel, several NDI technics have been tested on the elaborated samples in order to find industrial adapted ones.

Speaker: Magali ROLLIN
Name and Title: Dr. Ing. ROLLIN Magali
Affiliation and Position: MBDA, Ceramic Matrix Composites Process Technical Expert
Education and Degree: PhD Thesis, Engineer

HiSST 2024 - 330

STORT Hypersonic Flight Experiment CMC Thermal Protection System and Selected Flight Results

Thomas REIMER[1], Gisueppe Daniele DI MARTINO[1], Lucas DAUTH[2] Luis BAIER[1], Ali GÜLHAN[1], Florian KLINGENBERG[1], Dorian HARGARTEN[1]

[1]German Aerospace Center (DLR), Germany
[2]Bayern-Chemie, Germany

The DLR project STORT was focused on investigating key key technologies for flight at hypersonic Mach numbers of higher than 8. The main goal of the project is to enable cost reduction of future space transportation systems while keeping them reliable. To this end, reusability of the stages of a launcher system is a necessity. For first

stages, a Mach number of 8-10 seems to be the optimum staging velocity, which means that technologies for the return flight of first stages at those speeds need to be developed and validated. Consequently, STORT aimed at achieving such operating conditions at Mach 8, to support the optimization and validation of technologies and simulation tools for the development of future space transportation systems. The present paper describes the design, manufacturing and integration of the rocket forebody assembly. The forebody thermal protection system structures require the use of ceramic matrix composite material for protection from the high heat loads experienced during the flight. In the present case the thermal protection system was constituted by C/C-SiC composite structures built in-house by DLR. The main elements were a conical nose element and four thin-walled shell segments manufactured via filament winding of carbon fibers fitted with integral fixation brackets. In addition, selected flight data collected on the thermal protection system is presented.

Speaker: Thomas REIMER
Graduation in 1994 in Aerospace Engineering at Stuttgart University
Since 1994: Institute of Structures and Design of DLR in Stuttgart; dep.: Space System Integration
Position: Deputy Department Head

Thermal and Energy Management Systems 2 (TEM 2)

Chairs: Prof. Matthew MCGILVRAY (University of Oxford, UK), Prof. Hyung Ju LEE (Pukyung National University, Korea)

HiSST 2024 - 139

The Development of a Design Program for a High-speed Counter-flow Air Precooler

Xin ZHANG, Y. LU, XJ FAN

Institute of Mechanics, Chinese Academy of Sciences (IMCAS), China

The precooler is the core component of the precooled air-breathing combined engine, which is used to cool the incoming high-temperature air in a short time. A gas-solid-liquid coupled heat transfer program is developed to evaluate the flow heat transfer performance of a high-speed counter-flow air precooler. The program uses two methods to calculate the heat conduction of the solid. One is the "Node Current Method", which is suitable for rapid evaluation of the performance of the precooler. The other is the "Fenics Finite Element Platform", which is suitable for the performance evaluation of the precooler with complex structural shapes and stress analysis. The program can be used to evaluate the cooling performance of various coolants such as hydrogen, methane, ammonia and kerosene. The fuel cracking mechanism has been added to the program when calculating kerosene. The calculation results of two methods have been compare using hydrogen and methane as coolants. The relative error of calculated air outlet temperature is less than 1.1%. Kerosene with cracking mechanism has also been calculated when it is used to cool the 1800 K incoming air. To sum up, the high-speed counter-flow air precooler is suitable for the cooling of the air from Ma 2.5 to Ma 6.5, which corresponds to the temperature of 486 K to 1800 K. The program evaluates the heat transfer performance of the precooler well and is suitable for the evaluation of different forms of counter-flow air precooler.

Speaker: Xin ZHANG
Zhang Xin is engaged in performance analysis and optimization of precooled combined air engine and give an oral report entitled the development of a design program for a high-speed counter-flow air precooler.

HiSST 2024 - 152

Data Models for the Probabilistic Design of the Thermal Protection System of a Reusable Launch Vehicle Stage

Aaron Dexter KOCH, Jascha WILKEN, Marko ALDER

German Aerospace Center (DLR), Germany

Early design phases significantly impact a system's life-cycle costs, yet they are fraught with large uncertainties. Hence, it is important to incorporate uncertainties in preliminary design activities. However, sampling the uncertain design space instead of analyzing a single system entails a considerable computational cost. It also demands a high degree of automation, with data models being a crucial component. Consolidating all data describing a system in a structured way in a single source helps to streamline processes. This applies to the technical system itself as well as the description of the probabilistic study. The use of the Extensible Markup Language (XML) along with XML Schema Definition, complemented by libraries written in C++ with Python bindings via Boost.Python, has proven to be effective for implementing data models. This paper demonstrates the application of such data models through the sizing of a thermal protection system (TPS) of a reusable launch vehicle stage. The results indicate that a probabilistic design of a TPS can lead to a reduction in the required material thickness compared to a worst-case scenario.

Speaker: Aaron Dexter KOCH
Research Engineer in the Space Launcher System Analysis department of the German Aerospace Center (DLR), specializes in the digitalization of the launch vehicle design process and data models

HiSST 2024 - 060

Numerical Simulation of Flow/Heat Transfer/Thermal Decomposition Characteristics of Supercritical Hydrocarbon Aviation Fuel in a Minichannel

Minseo LEE, Hyung Ju LEE

Pukyong National University (PKNU), Korea

In a cooling channel of a regenerative cooling system of hypersonic cruise vehicles, a hydrocarbon aviation fuel is heated to a supercritical state, which leads to complex interactions between fluid flow, heat transfer, and thermal decomposition reactions. In order to understand such a complicated phenomenon, numerical analyses are conducted investigating the fluid flow resistance, heat transfer characteristics, and endothermic decomposition reactions of hydrocarbon fuel under supercritical conditions. The results showed the pressure drop increase and the Heat Transfer Deterioration (HTD) due to the abrupt variation in thermophysical properties above the pseudo-critical temperature. In addition, the numerical results of the endothermic decomposition reaction using n-dodecane's Proportional Product Distribution (PPD) model confirmed that hydrogen and various light hydrocarbons appeared in good agreement with the existing experimental data.

Speaker: Minseo LEE
Graduate Research Assistant (March, 2024 - Present)
Department of Mechanical Engineering, Pukyong National University, Busan, South Korea
B.S. Mechanical Engineering (March, 2020 - February, 2024) Pukyong National University, Busan, South Korea

HiSST 2024 - 214

Numerical Analysis of Non-equilibrium Effects using a Unified Solver

Seungyong BAEG, Raghava S. C. DAVULURI, Alexandre MARTIN

University of Kentucky, USA

Historically, efforts have been made to model the interaction between ablative material and hypersonic flow through coupling strategies. In this paper, a solver that uses a unified approach is considered to study for the gas surface interactions. The solver uses Volume Averaged Navier-Stokes (VANS) equations to solve for both porous material and hypersonic flow at the same time. The capability of the solver was assessed in the past by simulating the high speed flow in supersonic and hypersonic conditions through porous material. In the present work, high-speed flow simulations accounting the thermal non-equilibrium are run. More specifically, the two-temperature model proposed by Park [1] is implemented, where non-equilibrium effects at the gas-surface interface are studied.

Speaker: Seungyong BAEG
Mr. Seungyong Baeg received his bachelor's degree from the departmetn of Mechanical engineering at Kyungpook National University, and his masters degree from the department of Mechanical engineering at Hanyang University. He is pursuing his doctoral degree in the department of Mechanical and Aerospace department at the University of Kentucky.

HiSST 2024 - 274

Large-Eddy Simulation of Supercritical Hydrocarbon Flows in a Heated Horizontal Circular Tube

Shuto YATSUYANAGI, Hideyuki TANNO

Japan Aerospace Exploration Agency (JAXA), Japan

Large-eddy simulations of supercritical n-dodecane flow in a horizontal heated circular tube are conducted to clarify the hydrodynamic characteristics under supercritical pressure conditions. The hydrodynamic characteristics curves are evaluated for three different outlet pressure conditions of 2.0, 2.5, and 6.0 MPa. The present LES demonstrates that the hydrodynamic characteristics are expressed as cubic curves at 2.0 and 2.5 MPa conditions. The negative slope region in the hydrodynamic characteristics curve has been recognized as the cause of Ledinegg instability. The present results suggest that Ledinegg instability can occur in supercritical n-dodecane flow in a heated horizontal circular tube. The outcome of the present study contributes to the design of a highly efficient and reliable regenerative cooling system.

Speaker: Shuto YATSUYANAGI

He is a researcher working at JAXA Kakuda Space Center and has a PhD in Information Science. His research interests include numerical simulations of aerodynamic heating and boundary layer transitions in high enthalpy hypersonic flows.

NOTE

SHORT ABSTRACTS

APRIL 18
THURSDAY

ORAL PRESENTATION

High-Speed Aerodynamics and Aerothermodynamics 9 (HSA 9)

Chairs: Dr. Viola WARTEMANN (DLR, Germany), Prof. Tai JIN (Zhejiang University, China)

HiSST 2024 - 158

Application of HyperCODA to Hypersonic Flows Around Two-Dimensional Geometries

Chiara AMATO, Stefan FECHTER, Tim HORCHLERz, Immo HUISMANN, Tobias ECKER

German Aerospace Center (DLR), Germany

This paper aims to analyze the application of the flow solver HyperCODA to study problems of interest to hypersonic research and industrial application. The analysis focuses on exploring HyperCODA capabilities, validating its accuracy, and investigating computational requirements and efficiency in solving high enthalpy flows. To achieve this detailed study, we compare the solutions of the chosen test cases obtained with HyperCODA to the ones obtained using DLR CFD solver TAU and the experiment data from the High Enthalpy Shock Tunnel in Göttingen (HEG). In the current study, we simulate a two-dimensional 7/40 degree cone-flare flying at Mach 5.9 and different configurations of a sharp fin on a flat plate flying at Mach 7.4 based on the third stage fins of the STORT flight experiment conducted at DLR. In particular, these test cases are solved with an implicit time integration of RANS turbulence modeling using different numerical methods, such as finite volume and higher-order Discontinuous-Galerkin discretization. Furthermore, we consider a single perfect gas and a mixture with the assumption of an ideal gas with temperature-dependent fluid properties to further understand how more complex flow field configurations affect the comparison.

Speaker: Chiara AMATO
Chiara Amato is a DLR-DAAD PostDoc in the spacecraft department of the Institute of Aerodynamics and Flow Technology at the German Space Center (DLR). The current focus of her work is the development of numerical methods for the simulation of hypersonic flows and the application of the flow solver HyperCODA to study problems of interest to hypersonic research and industrial application.

HiSST 2024 - 112

Transient Analysis of the Conjugate Heat Transfer Analysis of Scramjet Engine Inlet

Jae-Eun KIM, Jeong-Yeol CHOI

Pusan National University (PNU), Korea

A conjugate heat transfer analysis was conducted for the High-speed vehicle inlet. We examined the internal flow and the structure temperature variations over time. In the time frame of less than 10 seconds, noticeable differences in the internal flow were observed along with rapid heat conduction. However, after 10 seconds, apart from the solid temperature on the upper wall, there were no noticeable differences in the internal flow patterns. In the constant wall temperature condition, the solid domains temperature increased similarly to the adiabatic condition, but the wall temperature was not heated above a certain level.

Speaker: Jae-Eun KIM
I am coming from Pusan National University. I am researching the Scramjet engine by CFD.

HiSST 2024 - 159

Direct Numerical Simulation of Supersonic Reacting Mixing Layers

Nicholas GIBBONS, Lachlan WHYBORN, Vincent WHEATLEY

The University of Queensland (UQ), Australia

A pair of high fidelity direct numerical simulations have been developed to study the interaction between turbulence and chemistry in high-speed combustion. One case considers a time-developing hydrogen/air turbulent mixing layer taken from the literature, aiming to verify and demonstrate a newly improved high-fidelity numerical scheme, and the other will investigate a hydrocarbon, i.e. ethylene, combustion at effectively the same conditions. The numerical method that has been developed uses a novel technique for detecting discontinuities to hybridise a low dissipation, central inviscid flux scheme, with a high-dissipation, shock capturing scheme. The method is successfully verified against the analytic solution for a steepening nonlinear wave, then applied to the two mixing layer cases. The results show a number of striking differences between the hydrogen and ethylene cases, including very different regimes of premixed vs. nonpremixed combustion and different patterns of heat release over time. Conditional statistics also show both cases have large variations in temperature that are not correlated with mixture fraction, an important finding that will need to be addressed in model developments for highly compressible combustion flows.

Speaker: Nicholas GIBBONS

Nick Gibbons is a hypersonics expert with an interest in turbulence, propulsion, and high-speed flow. He was awarded a PhD in supersonic combustion in 2019, and since 2020 has been a core developer of the UQ's open-source hypersonics code Eilmer.

HiSST 2024 - 078

Development and Verification of Nonequilibrium Hypervelocity Reacting Flow Modeling in Open Source Framework

Kun WU[1], Yu AO[1], Yuting JIANG[2], Jianwen LIU[3], Xuejun FAN[1]

[1]Institute of Mechanics, Chinese Academy of Sciences (IMCAS), China
[2]Hefei Zhongke Chongming Technology Company, China
[3]Beijing Power Machinery Institute, China

Computational fluid dynamics (CFD) approach has become a crucial part of the design and study of modern high-speed space vehicles in recent years. In this work, a transient threedimensional nonequilibrium CFD solver HiSCFOAM-NonE is developed in OpenFOAM to accomplish the computation of the hypervelocity reacting flows invovled in high Mach number scramjet engines. By coupling with the state-of-the-art thermal-chemical non-equilibrium package Mutation++, this solver is capable of simulating the chemical-reacting flow in scramjets operating in wide flight Mach numbers ranging from 8 to 15. The solver was primarily validated against a set of elementary benchmarks including zero-dimensional heat bath, high Mach number cylinder flow as well as complex shock-dominated flow in a model scramjet, wherein satisfactory agreements were obtained with the currently available experimental data.

Speaker: Kun WU

Dr. Kun Wu is an associate professor at the institute of Mechanics, Chinese Academy of Sciences. He received his PhD from the University of Chinese Academy of Sciences in 2018 and worked as a research assistant at The Hong Kong Polytechnic University during 2016-2017. His expertise is in the development of physical models and modeling methodologies of turbulent combustion in space propulsion systems. He is partially interested in droplet and spray dynamics concerning liquid fuels' atomization in propulsion systems. Dr. Wu is a member of AIAA and the international combustion institute. He also serves as an active reviewer for many top-tier journals.

HiSST 2024 - 105

Numerical Calculations of Hypersonic Nonequilibrium Flowfields over a Sphere using hy2Foam CFD Software

Jianshu WU, Michiko AHN FURUDATE

Chungnam National University (CNU), Korea

For designing thermal protection system(TPS) of atmospheric entry vehicle, accurately predicted the heat flux to the surface is necessary. The criteria to validate the reliability of thermochemical model which in Computational Fluid Dynamics(CFD) to describe the high-temperature real-gas phenomena in hypersonic flowfield is shock stand-off distance(SSD) for a sphere, because the thickness of shock layer varies according to the temperature and pressure due to chemical reaction. In this paper, an open-source hypersonic flow solver, hy2Foam, is examined in terms of the shock stand-off distance using Park's two-temperature model, a standard thermochemical model for the atmospheric entry flow and the computation results generally agree well with experimental results by Lobb and Nonaka and the previous calculation results of Furudata, and it shows the SSD is more sensitive to the definition of the dissociation controlling temperature than the differences in the viscosity model or the slip/nonslip wall conditions.

Speaker: Jianshu WU

Jianshu WU is a dedicated master's student at Chungnam National University. He specializing in computational fluid dynamics (CFD) with a focus on chemical reacting non-equilibrium flow.

Chairs: Prof. Eunji JUN (KAIST, Korea), Prof. Zhi-Hui WANG (University of Chinese Academy of Sciences, China)

HiSST 2024 - 186

A Standard Model for the Investigation of Aerodynamic and Aerothermal Loads on a Re-usable Launch Vehicle - Second Stage Geometry

Moritz ERTL, Tamas BYKERK

DLR - Deutsches Zentrum für Luft- und Raumfahrt, Germany

This paper presents a generic geometry for the study of aerodynamic and aerothermal behaviour of an upper stage compatible with the RFZ model, a generic, open source geometry of a re-usable launcher. The vehicle design is presented, outlining simplifications made to retain key features of the vehicle while ensuring a manufacturable and meshable geometry. Computational studies will be performed at altitudes between 70 and 90 km, reflecting the phase directly after staging up to the limits of the continuum flow regime. The geometry and results will be made openly available to the research community to promote collaboration in understanding the design challenges associated with re-usable launchers.

Speaker: Moritz Ertl

Moritz Ertl is a Research scientist at the German Aerospace Center, Institute of Aerodynamics and Flow Technology, Department of Spacecraft, Aerothermodynamics and Propulsion Technology group. He did his PhD in Aerospace Engineering at Stuttgart University, where he worked on the direct numerical simulations of oscillating droplets and liquid jet-breakup of non-Newtonian fluids. For the past five years he has been working on both aerothermodynamics for reusable launch vehicles and multiphase flow simulations for tank sloshing. He is part of the CALLISTO project, a French, Japanese and German cooperation developing a demonstrator for reusable launch vehicle technology. His research includes CFD simulations for the prediction of aerodynamic and aerothermal loads on both system and part level for vehicle configurations with plume vehicle interactions in backward flight, simulations of plume ground interaction for start and landing and the investigation of the influence of secondary outlets, such as bleed nozzles or gas generator exits on thermal loads. Furthermore, he is doing code development on DLRs next generation flow solver for multi-phase flow simulations using the volume of fluid method with the aim of simulating tank sloshing in upper stages.

HiSST 2024 - 162

Numerical Simulation of Multi-Temperature Thermochemical Non-Equilibrium Model Over High Enthalpy Flow

Chanho KIM[1], Yosheph YANG[2], Jae Gang KIM[3], Kyu Hong KIM[1]

[1]Seoul National University (SNU), Korea
[2]Kangwon National University (KNU), Korea
[3]Sejong University

In hypersonic computational fluid dynamics studies, using a two-temperature model to simulate thermochemical non-equilibrium states is common. The two-temperature model assumes translational-rotational, electron-electronic-vibrational temperatures and includes the assumption that each energy has an equal temperature. In this study, the temperature of each energy mode was separated and the effects were analyzed. The three-temperature model uses translational-rotational, vibrational, and electron-electronic temperatures by independently calculating the electron-electronic temperature from the two-temperature model. The four-temperature model calculated the rotational temperature independently. To accurately calculate

the electron-electronic temperature, not only the Lee model but also the Laporta model was used to model the e-V relaxation time of *NN*2, *OO*2, *NNNN*. The validation of the multi-temperature model solver was performed by comparing the heat flux of ELECTRE, LENS-XX experiments, and the electron number density of RAM-C. The effect of the multi-temperature model is most pronounced in the wake region, where the flow expands and affects the formation of ions and electrons.

Speaker: Chanho KIM
2016~2022: B.S. in Mechanical Engineering, Kyunghee University 2022~2024: M.S. in Interdisciplinary Program in Space System, Seoul National University 2024~present: Ph.D. in Department of Aerospace Engineering, Seoul National University

HiSST 2024 - 170

Direct Numerical Simulation of Strong Shock-turbulent Boundary Layer Interaction

Yujoo KANG, Sang LEE

Korea Advanced Institute of Science and Technology (KAIST), Korea

In this study, the direct numerical simulation (DNS) analysis around the strong shock-turbulent boundary layer interaction over 24° compression ramp with Mach 2.9 flow is carried out. To enhance the precision of the numerical simulations, a novel, proprietary code has been developed based on a compact finite difference scheme. This compact scheme is supplemented with a low-pass filter and localized artificial diffusivity to effectively mitigate numerical oscillations. The obtained DNS results are rigorously validated through comparison with experimental data and pre-existing DNS data. A noteworthy milestone achieved in this research is the successful validation of the statistical characteristics of the flow downstream of the STBLI, a validation that has hitherto not been achieved in DNS simulations.

Speaker: Yujoo KANG
- Affiliation and Position: PhD candidate, Korea Advance Institute of Science and Technology
- Education and Degree:
  B.S. in Aerospace Engineering - Korea Advance Institute of Science and Technology, 2021
  M.S. in Aerospace Engineering - Korea Advance Institute of Science and Technology, 2023

HiSST 2024 - 231

Verification of Nonequilibrium Chemistry Model for Hypersonic Computational Fluid Dynamics against First-principles Molecular-dynamics Simulations

Erik TORRES, Thomas E SCHWARTZENTRUBER

University of Minnesota (UMN), USA

We perform verification studies of the Modified Marrone-Treanor multi-temperature nonequilibrium chemistry model for computational fluid dynamics on several canonical flow fields. Reference solutions suitable for testing the model in scenarios applicable to hypersonic flight and ground test facilities have been generated via first-principles Direct Molecular Simulations. This molecular-scale simulation method relies exclusively on ab initio potential energy surfaces generated by computational chemists to predict the chemical and thermodynamic evolution of the flow field. The Modified Marrone-Treanor model for CFD has been built upon a consistent foundation by employing kinetic rates and vibrational energy-chemistry coupling terms derived from the same potential energy surfaces.

Speaker: Erik TORRES
Research Associate in Department of Aerospace Engineering and Mechanics, University of Minnesota, USA 2017 - Doctorate in Aerospace Engineering from University of Stuttgart, Germany

HiSST 2024 - 164

Rapid Design Method for Planform-customized Waveriders Based on the Second-order Curved Shock Theory

YiQi TANG, Zhancang HU, Xiaoting DING, Xiaogang ZHENG, Chongguang SHI, Yancheng YOU

Xiamen University, China

The planform shape of waveriders is closely bound up with waveriders' geometric properties and aerodynamic characteristics. To enhance design freedom and efficiency, a rapid design methodology for planform-customized waveriders is proposed in this paper. The more general geometrical relationships between design curves are revealed, and an approximate analytical method for solving the post-shock flowfield is derived based on the second-order curved shock theory. The double-swept waverider and the delta-winged waverider are designed respectively. Numerical simulation results indicate that this method substantially enhances computational efficiency while maintaining high accuracy. The influence of angle of attack on the aerodynamic performance of the waverider is investigated by viscous numerical simulation. It is found that the lift coefficient of the waverider increases nonlinearly with the angle of attack under design conditions. This method broadens the design idea of the planform-customized waveriders and promote its engineering application.

Speaker: YiQi TANG
YiQi TANG is a doctoral student at the Xiamen University

HiSST 2024 - 241

An Exploration of Adjoint-based Optimization for Hypersonic Vehicle- and Propulsion Design

Carola Rovira SALA[1], Marc Famada VIZCAINO[1,2], Alberto Simon FELIX[1], Ambara BERNABEU-VAZQUEZ[2], Bart VAN HOVE[3], Tamas Istvan JOZSA[1], Jimmy-John O.E. HOSTE[3]

[1]Cranfield University, UK
[2]Destinus SA, Switzerland
[3]Destinus Spain S.L., Spain

The design of hypersonic vehicles and hypersonic propulsion systems is a challenging endeavor. Affordable large-scale computational systems have made CFD more accessible, including for optimization related tasks. Adjoint optimization methods, that were previously in the realm of research, are now available in commercial software. This work explores the use of adjoint-based optimization for hypersonic vehicle design in two case studies on external and internal hypersonic flows using a commercial CFD software. For the external flow problem, lift over drag is maximised for a waverider geometry while considering various constraints. In the internal flow case, proxy measures of mixing efficiency are maximised to improve combustion efficiency inside a hydrogen scramjet geometry using adjoint CFD. Both the advantages and the limitations of adjoint-based optimization are evaluated.

Speaker: Jimmy-John O.E. HOSTE
Jimmy-John is an Aerothermodynamics and Combustion Engineer at Destinus (www.destinus.ch), a Swiss start-up aiming to revolutionize hypersonic cargo transport. His present work targets the design and optimisation of high-speed aerospace vehicle systems based on CFD. Before joining Destinus, he worked as a postdoctoral

researcher at CERFACS (2020-2021) and DLR (2018-2020). He completed his PhD in scramjet propulsion at the University of Strathclyde (2014-2018) in collaboration with the University of Queensland following a postgraduate degree in CFD at Cranfield University and an Aeronautical Engineering MSc from the Free University of Brussels.

Propulsion Systems and Components 10 (PSC 10)

Chairs: Dr. Inyoung YANG (KARI, Korea), Dr. Marco MARINI (CIRA, Italy)

HiSST 2024 - 253

Temperature Field Measurement of External Flash Boiling Spray in Region where Bubbles Generate and Grow

Hyunchang LEE

Kyungnam University, Korea

Modern high-performance engines like liquid rockets, gas turbines, and hypersonic scramjets use regenerative cooling. As a result, superheated fuel is likely to be injected into combustion chamber. Here, flash boiling spray is likely to occur for the lower pressure in the chamber, and the mechanism of generation and growth of bubble should be thoroughly understood in the regards of heat transfer. In this study, temperature field in the region where bubbles generate and grow has been measured by using 2-color-ratio laser induced fluorescence method using Eosin Y as the dye. The effect of dye on flash boiling spray has been assessed by comparing discharge coefficient before and after mixing the dye. The crosstalk of laser fluence and dye concentration on intensity ratio of 2c LIF image has been investigated, too. Based on measured consecutive temperature fields in high repetition rate, detailed heat transfer between the jet and the ambient, heat flow into the region of phase change could be investigated. Heat transfer affects bubble dynamics significantly and measured temperature fields in this study will support numerical model validation.

Speaker: Hyunchang LEE
My research interest is an application of laser diagnostics to liquid propulsion system, e.g., appearance of spray, droplet diameter, temperature, velocity measurement, etc. At the moment I am studying flash boiling spray. I working as an assistant professor in Kyungnam Univ., Korea.

HiSST 2024 - 121

Numerical Analysis of Confined Supersonic Combustion Fueled via a Fluidic Oscillator

Guillaume PELLETIER

ONERA, France

Reactive Delayed Detached Eddy Simulations (DDES) were performed to investigate the effects of oscillatory hydrogen injection into a confined transverse supersonic flow of vitiated air. The corresponding experimental conditions were studied in the LAPCAT-II combustor, operating in the LAERTE facility at the ONERA Palaiseau Research Center. The core concept underlying this investigation revolves around the application of a fluidic oscillator, a device capable of inducing oscillatory motion in fluid flow, devoid of any mechanical components. In this context, oscillatory injection is harnessed to enhance the mixing efficiency within the combustor. Moreover, the study delves into another effect of the fluidic oscillator, the ability of sweeping injection to delay the onset of thermal choking within the combustor. This phenomenon has been identified as closely related to a specific structural interaction involving the boundary layer, shockwaves, and combustion processes. Improved mixing of fresh gases is demonstrated to mitigate this phenomenon, thus extending the operational envelope of the scramjet engine. The primary focus of this paper centers on the combustor's response to various fluidic oscillators, encompassing a range sweeping angles. Comparative assessments of mixing and combustion efficiencies are conducted.

Speaker: Guillaume PELLETIER
Guillaume Pelletier is a research engineer at ONERA, specializing in the study of scramjet engines through advanced numerical simulations. His recent simulations where focused on the LAPCAT-II dual mode ramjet scramjet test section located ate ONERA Palaiseau.

HiSST 2024 - 149

Characterizations of Combustion Destabilization in an Axisymmetric Supersonic Cavity-based Combustor

Qinyuan LI, Bo YAN, Mingbo SUN, Jiajian ZHU, Yifu TIAN, Minggang WAN, Tiangang LUO, Yongchao SUN

National University of Defense Technology (NUDT), China

Three-dimensional characterizations and evolution laws of the flame structure during combustion destabilization in an axisymmetric supersonic combustor were investigated. The multi-view OH-PLIF imaging system was used to visualize the instantaneous flame structures distributing at multiple typical cross-sections of a fully transparent axisymmetric supersonic glass combustor. The high-speed photography and pressure measurement systems were employed to assist in the analysis of the flame structure evolution during combustion destabilization. The experiments were conducted with an inflow speed of Mach 2.5 and a total temperature of 1800 K. The global equivalence ratios (GER) were 0.12, 0.15, 0.21 and 0.26, respectively. It was found that a loop-shaped flame with a central hole is an essential flame structure characterization in the axisymmetric supersonic combustor. The flame loop mainly distributes near the cavity shear-layer, and the instantaneous structure fluctuates over time. There is the most intense combustion and thickened flame near the cavity ramp. As GER exceeds 0.21, an excessive enhanced combustion induces thermal choking. The flame propagates upstream away from the cavity along the boundary-layer near the jet wake. It leads to a violent reciprocal flame propagation, marking an unsteady combustion. The thermal choking initiates near the ramp where the most intense combustion occurs. The local flame loop is significantly expanded, filling almost the entire flow path. The loop-shaped flame structure downstream the combustor is affected slightly due to a low-speed and thickened cavity shear-layer. In contrast, the flame structure near the middle part of the combustor is disrupted severely. A diffused and fragmented flame loop fluctuates violently over time. A large amount of fragmented flames spread into the core flow occasionally.

Speaker: Qinyuan LI
Qinyuan Li, born in 1995, received the Master's degree of Engineering in Aeronautical and Astronautical Science and Technology from National University of Defense Technology, Changsha, China, in 2023. He is currently working toward the Ph.D. in Aeronautical and Astronautical Science and Technology at National University of Defense Technology, Changsha, China. His research interests include plasma control for supersonic combustion and flame visualization in scramjet.

HiSST 2024 - 185

Investigation of Mixing and Combustion in Supersonic Flows

Sasi Kiran PALATEERDHAM [1], L N PHANEENDRA PERI[1], Antonella INGENITO[1], Gautam CHOUBEY[2]

[1]Sapienza University of Rome, Italy
[2]National Institute of Technology (NIT) Silchar, India

The significance of green transportation at hypersonic speeds is the current field of research for space launchers and commercial trans atmospheric vehicles. However, due to their high speeds at Mach > 1, results in a very short residence time of the order of few milliseconds (10-3 – 10-4 s) minimizing the chances for air-fuel barely mix and burn. Furthermore, the interaction of fuel injection at sonic speed via transverse and cross flow with incoming airstream at high Mach results in the generation of complex vortices that effect the chemical kinematics and

combustion and are influenced by the dilatational term "∇.U". therefore, the supersonic combustion region is affected by compressibility and the corresponding baroclinic terms. Thus, it is very important to realize the behavior of flow while different injection angles, the geometry of the cavity and the corresponding flow behavior. This could be realized by the numerical simulation of flow to better understand the physics of supersonic combustion. Therefore, the current study plans to understand the shock and how it interacts with fuel injection and mixing, the resulting vorticity development, the effects of adding heat and boundary layer separation on total pressure loss by utilizing large eddy simulations.

Speaker: Antonella INGENITO
Professor of Hybrid Propulsion and New Launch Systems at the School of Aerospace Engineering, Sapienza, University of Rome. Head of the Aerospace Propulsion Laboratory, ASPLab. Since 2006, she has been involved in national and international research projects focusing on hypersonics, particularly in the areas of propulsion, engine and vehicle design, as well as the correlation between ground and flight tests (LAPCAT project). Since 2020, she has been a member of the NATO STO AVT group (Science Technology Organization, Applied Vehicle Technology Panel) and the International Academy of Astronautics (IAA). Professor Ingenito has authored over 90 international publications and a monograph on ramjet engines.

HiSST 2024 - 151

Longitudinal Acoustic Field in a Two-Phase Ramjet: Numerical Simulation and Acoustics Model

Erwin BEKAERT[1], Aurelien GENOT[1], Thomas LE PICHON[1], Thierry SCHULLER[2]

[1]DMPE, ONERA, Université Paris Saclay, France
[2]Institut de Mécanique des Fluides de Toulouse (IMFT), France

Thermoacoustic instabilities are recurrent in ramjets and may cause thermal and mechanical fatigue, as well as engine extinction. To study and predict the development of such instabilities resulting from the coupling between pressure and heat release rate fluctuations, the internal acoustic field itself needs to be characterized and predicted. As a first step, a description of the acoustic field in a two-inlet sidedump ramjet in a liquid-fuelled configuration is proposed relying on numerical simulations. Two predominant oscillation modes are identified by spectral analysis. Their origin and spatial structure are investigated comparing the numerical results with a linear acoustics reduced-order model for pressure fluctuations. Lastly, complex phenomena observed by numerical simulation are studied by an ad hoc correction of the linear acoustic model introducing a harmonic translation velocity to the mode shape, replicating the trends observed numerically.

Speaker: Erwin BEKAERT
Erwin BEKAERT graduated from INSA Rouen in 2021 in mechanical engineering and is now in his third year of PhD at the ONERA laboratory, working on thermoacoustic instabilities in ramjets.

HiSST 2024 - 349

Spray Characteristics of High Energetic Powder Added Low-Temperature Gel Fuel Using Pressure Swirl Injector

Dong-Geun LEE, Sul-Hee KIM, In-Woong LEE, Dong-Hee LEE, Hee-Jang MOON

Korea Aerospace University (KAU), Korea

Hypersonic air-breathing propulsion systems primarily utilize regenerative cooling, employing endothermic fuels to cool the high temperature inflow air. However, the phenomenon of coking in the fuel due to high temperatures within the cooling channels poses a significant challenge. Adding metal particles which form organometallic compound, or gelling fuels which enhance the thermal stability of the fuel, are known to mitigate

the coking issue. Therefore, application of metallized gelled fuel may be a reasonable future fuel candidate for preventing coking. However, gel type fuels are characterized by its high viscosity and also by viscosity variations with temperature. This academic study aims to investigate spray characteristics in low-temperature environments using spray visualization experiments with a pressure swirl injector. Spray angles and break-up lengths were measured from the visualization images, revealing that viscosity changes based on temperature dominantly influence the spray characteristics in low-temperature conditions.

Speaker: Dong-Geun LEE
Affiliation and Position: Graduate School of smart Aerial Mobility, Korea Aerospace University, Ph.D. candidate.
Education and Degree: Ph.D. candidate, master degree

Propulsion Systems and Components 11 (PSC 11)

Prof. Hyung Sub SIM (Sejong University, Korea), Dr. Christoph KIRCHBERGER (DLR, Germany)

HiSST 2024 - 350

Numerical Study of Reactive Flow dynamics in a Hydrogen-fueled Direct-Connect Scramjet Combustor depending on Number of Injector

Seung-Min JEONG[1], Jae-Eun KIM[2], Jeong-Yeol CHOI[2]

[1]Korea Aerospace Research Institute (KARI), Korea
[2]Pusan National University (PNU), Korea

This study numerically investigated the reactive flow dynamics of a laboratory-scale gaseous hydrogen-fueled scramjet combustor depending on the number of injectors. The present study's primary goal is to investigate a flame structure and combustion dynamics by changing fueling schemes and to reveal the effect of injector schemes on combustion performance. A numerical simulation was performed using an improved delayed detached eddy turbulent model (IDDES) and Jachimowski's hydrogen-air reaction mechanism. The simulation utilized high-order accuracy-based numerical schemes to ensure high-resolution and fidelity results. Single and multi-injectors with five equivalence ratio cases in one set were considered for a quantitative comparison of the effect of injector schemes. Comprehensive numerical results found intricate coupled fluid-combustion dynamics and their transition depending on the fueling schemes and global equivalence ratio. A counter-rotating vortex pair (CRVP) of the multi-injector case was not maintained, resulting in decreased fuel/air mixing and combustion performance. Due to this phenomenon induced by an interaction between the jet-jet and jet-wall surface, it was revealed that the combustion efficiency is significantly reduced for the multi-injector compared to the single-injector under a similar global equivalence ratio. These findings indicated that the multi-injector scheme cannot guarantee increased mixing and combustion performance of a scramjet combustor without meticulously considering the interaction between the injector-to-injector and injector-to-wall surface.

Speaker: Seung-Min JEONG
Dr. Seung-Min Jeong is an Aerospace Engineering at the Korea Aerospace Research Institute (KARI).

HiSST 2024 - 184

Experimental Investigation of Combustion Mode Transitions in a Cavity-based Scramjet

Le LI, Jiajian ZHU, Minggang WAN, Yifu TIAN, Tiangang LUO, Qinyuan LI, Shuaijia SHAO, Mingbo SUN

National University of Defense Technology (NUDT), China

he combustion mode has a great influence on the scramjet thrust. Different combustion modes correspond to distinct flame structures and pressure along the scramjet combustor. This paper focused on the combustion mode transitions in a cavity-based scramjet under a Mach number of 2 and a total temperature of 940 K. Five cases with various fuel injection positions and global equivalence ratios were investigated using the wall-pressure measurement and high speed chemiluminescence imaging. The combustion modes were then identified on the basis of the chemiluminescence intensity, flame front position, and wall pressure distribution. The experimental results showed that the combustion mode changed during the ignition process due to the improved back pressure, and finally maintained the cavity shear-layer mode. As the fuel injection position moved along the upstream direction and the global equivalence ratio increased, the chemiluminescence intensity was improved. It was further observed the combustion oscillation was reduced when enlarging the distance between the fuel injection and the cavity fore wall which enhanced.

Speaker: Tiangang LUO
Tiangang luo, a doctoral student from National University of Defense Technology.

HiSST 2024 - 181

Numerical/Experimental Study Dual Injection in Supersonic Cross Flow

Sem DE MAAG[1], Jan Siemen SMINK[2], Edwin T.A. VAN DER WEIDE[2], Harry W.M. HOEIJMAKERS[2], Cornelis H. VENNER[2]

[1]TNO, Defence, Safety & Security, Netherlands
[2]University of Twente, Netherlands

Numerical and experimental study of tandem dual jet injection in a supersonic cross flow. In the numerical study the flow is numerically simulated in a supersonic wind tunnel with dual injection ports along one of its walls. The results are obtained in the form of distributions of flow quantities and in the form of Schlieren images. In the experimental study the flow in the supersonic tunnel with dual injection of sonic under-expanded jets is visualised by a Schlieren system. The Schlieren images are processed semi-automatically in order to obtain the time-dependent location of the upper shear layer of the (main) jet, from which a measure of the penetration depth is obtained.
The parameters varied are the ratio of the momentum of the jet and that of the free stream and the distance between the two jets in tandem. The Mach number ranges in between 1.5 and 1.8. The data obtained in the experiments are used as mutual valiadation of numerical results and measured results.

Speaker: Jan Siemen SMINK
Jan Siemen Smink is PhD student in the Engineering Fluid Dynamics Group at the University of Twente in Enschede, the Netherlands. He studied Mechanical Engineering and graduated in the aforementioned group. He worked on jet injection into a supersonic crossflow, experimentally. Currently, he is also involved in research into jet dynamics and optimization of fluidic networks.

HiSST 2024 - 351

Numerical Investigation on the Flow Dynamics of Interaction between Two Liquid-liquid Bi-swirl Injectors

Vishnu NATARAJAN, Jongsu OH, Jeong-Yeol CHOI

Pusan National University (PNU), Korea

In this study, numerical simulations were conducted using a validated multiphase solver implemented in OpenFOAM to investigate the flow dynamics between two bi-swirl injectors. The Volume of Fluid (VOF) method was employed to capture interface interactions, while an LES one-equation eddy viscosity model was utilized for turbulence modeling. Two scenarios were examined: one with both injectors swirling in the same direction, and another with opposite swirl directions. Detailed analyses were conducted on the flow dynamics inside the injectors and the spray characteristics outside. The examination included the convergence and interaction of the injector sprays, their influence on the internal flow field, and the alterations arising from the merging of these sprays.

Speaker: Jongsu Oh
Jongsu Oh is a second-year master's student at Pusan National University's Rocket Propulsion Laboratory (RPL). He is studying numerical analysis of injectors using OpenFOAM.

HiSST 2024 - 293

Influence of High-density Energetic Particles on Combustion of Solid Fuels for Ramjet Applications

Sasi Kiran PALATEERDHAM[1], Abdul RAHMAN[1], Sri Nithya MAHOTTAMANANDA[2], Yash PAL[3], Antonella INGENITO[1]

[1]Sapienza University of Rome, Italy
[2]BS Abdur Rahman Crescent Institute of Science & Technology, India
[3]Hindustan Institute of Technology and Science (HITS), India

In solid fuel Ramjet engine, the performance is impacted by fuel energy density and combustion behaviour which is a key for the total impulse. However, in terms of intensive properties, impulse density is more important than particular impulse, although the two variables do not need to be mutually unrelated. Since impulse density is the combination of material density, an increasing specific impulse increases impulse density. The impulse density, on the other hand, grows linearly with the material density, but the particular specific impulse grows proportionately to the square root of the flame temperature or heat release. As a result, increasing the fuel density has the greatest direct influence on impulse density and, eventually, the overall impulse of the vehicle. Increasing fuel density can be achieved by adding additives and energetic particles to the fuel matrix. Thus, the goal of the work is to improve the impulse density of the Ramjet solid fuels by adding high energetic materials such as Boron (B), magnesium diboride (MgB2), Carbon Black (CB) and magnesium (Mg), Titanium, Cerium oxide (CeO2) into Paraffin and HTPB based fuel matric. The performance characteristics of these solid fuels is by conducting thermogravimetric, Differential scanning calorimeter analyses, bomb calorimetry, mass spectroscopy, and ballistic fire testing. According to the test results, the material decomposes at a relatively low temperature and mostly into gaseous species with autoignition temperatures lower than the peak decomposition temperature. The fuel grain testing results show consistent combustion and acceptable regression rates. Based on the data gathered, the current study shows an ideal solid fuel for SFRJ applications. A detailed comparison of these solid fuels and their characteristics is given in this paper.

Speaker: Antonella INGENITO
Professor of Hybrid Propulsion and New Launch Systems at the School of Aerospace Engineering, Sapienza, University of Rome. Head of the Aerospace Propulsion Laboratory, ASPLab. Since 2006, she has been involved in national and international research projects focusing on hypersonics, particularly in the areas of propulsion, engine and vehicle design, as well as the correlation between ground and flight tests (LAPCAT project). Since 2020, she has been a member of the NATO STO AV T group (Science Technology Organization, Applied Vehicle Technology Panel) and the International Academy of Astronautics (IAA). Professor Ingenito has authored over 90 international publications and a monograph on ramjet engines.

HiSST 2024 - 232

Extension of the Lean Blow-off Limit in the Scramjet Combustor by the Multi-channel Gliding Arc Plasma

Rong FENG, Zhipeng MENG, Jiajian ZHU, Bo WANG, Mingbo SUN, Xiaoqing CHEN, Chao DING

National Innovation Institute of Defense Technology, China

A multi-channel gliding arc (MCGA) plasma is utilized to extend the lean blow-off limit of the cavity shear-layer flame in the scramjet combustor. Optical measurements including high-speed flame chemiluminescence, high-speed CH*emissions, and high-speed schlieren are used to characterize the reaction zone coupled with the flow field assisted by the plasma. The results show that the lean blowoff limit of the cavity shear-layer flame is extended by 21% when the MCGA plasma is added. The flame is blown out eventually due to a small amount of heat release near the lean blow-off limit. While the plasma is applied, the plasma can sustain the flame in the whole combustion process. The center of the flame tends to be concentrated near the plasma region,

indicating that the flame is more likely to attach to the MCGA plasma. The heat release of the mainstream flame is strengthened by the MCGA plasma to prevent extinguished. A plausible mechanism for the extension of the lean blow-off limit is revealed that the temperature is enhanced by the heat and active radicals produced by the MCGA plasma, which sustain the flame near the plasma region. Subsequently, the small flakes of the flame spread to the half back of the cavity to form the global flame with approximate local conditions.

Speaker: Rong Feng
Dr. Rong Feng is an assistant researcher at the National Innovation Institute of Defense Technology.

Prof. Gisu Park (KAIST, Korea), Dr. Sandy TIRTEY (Rocket Lab, Australia)

HiSST 2024 - 050

Prediction of Static and Dynamic Derivatives of Damping Free-flight Model using Image Processing Method

Eunju KIM, Soo Hyung PARK

Konkuk University, Korea

To evaluate an aircraft's aerodynamic characteristics, measuring its aerodynamic coefficients is essential. The conventional method involves using a balance, where the model is mounted on a sting, introducing additional drag. To obtain dynamic stability derivatives, it requires additional experiments like the forced vibration method. To enable the model to fly with 6 Degrees of Freedom (6-DOF), the sting must be eliminated, leading to the development of the free-flight technique. This approach allows experiments in flight conditions, with obtained coefficients combining static and dynamic effects. Separating these coefficients into static and dynamic derivatives enables the acquisition of both types in a single experiment, demonstrating the efficiency of the method for obtaining aerodynamic coefficients. In this study, a damping free-flight model was designed to obtain both static and dynamic coefficients. A free-flight experiment was conducted in KULT (Konkuk University Ludwieg Tube). The Angle of Attack (AOA) for the model was determined using the Hough Algorithm, extracting information from images. The model's AOA can be derived from the slope of the straight line, and x and y velocities can be obtained from both endpoints. The aerodynamic coefficients obtained in the free-flight experiment represent a combination of static and dynamic coefficients. In this research, the multiple linear regression technique was employed to separate these coefficients into static and dynamic derivatives.

Speaker: Eunju Kim
Eunju Kim is a Ph.d Student at the Konkuk University

HiSST 2024 - 154

Aero-Thermal Study and Experimental Characterization of a Novel Optical Probe for High Temperature Supersonic Flows

Ignacio LASALA AZA[1], Aubrey MCKELVY[1], Guillermo PANIAGUA-PEREZ[1], Etienne CHOQUET[2] Thierry ANDRÉ[2], François FALEMPIN[2]

[1]Purdue University, USA
[2]MBDA, France

This paper details the design and development of a cooled nacelle that allows the placement of the focusing optics anywhere within a high-temperature and high-speed flow while minimizing flow disturbances in the interrogation region. This study presents the design, thermal analysis and experimental testing of a streamlined probe that allows the placement of sensitive diagnostic hardware in high-speed flows with total temperatures up to 1700 K. The optical hardware is cooled using an open cycle gaseous cooling jacket terminating in a pattern of backward oriented ejection holes. The cooling channels have been sized using a 1D heat transfer model for subsonic and transonic conditions. The effect of theejected coolant on reducing the recovery temperature is also modelled, and reductions up to 50% have been found at high-temperature transonic conditions (Mach = 0.85, static temperature of 1500 K) with moderate blowing ratios (BR = 2) and room temperature coolant. A parametric study using 3D Reynolds-Averaged Navier-Stokes (RANS) simulations analyzes the adiabatic cooling effectiveness at supersonic Mach numbers closer to design conditions (Mach = 1.5, 2.3, 3), showing an increase

in effectiveness with respect to subsonic cases for the same blowing ratios. Flow disturbance by the bow shock has also been extracted from the parametric study, imposing a minimum laser standoff distance of ~10 cm at Mach 3, that is further reduced with higher Mach numbers, enabling the use of short focal length lasers diagnostics. Experimental tests have been performed with an additively manufactured probe body at the Purdue Experimental Turbine Aerothermal Laboratory (PETAL) to further analyze the cooling performance of the probe. Surface temperature and heat flux were measured for this purpose.

Speaker: Ignacio LASALA AZA
Ignacio Lasala Aza is a Graduate Research Assistant at Purdue University. He conducts research in aerodynamics and heat transfer of a probe for high-speed and high-enthalpy flows at the Purdue Experimental Turbine Aerothermal Laboratory (PETAL).

HiSST 2024 - 321

Nozzle Flow Characterization of the SNU Hypersonic Shock Tunnel

Jinyoung KIM, Jinhwi KIM, Jungmu HUR, Bok Jik LEE, In Seuck JEUNG

Seoul National University (SNU), Korea

This paper presents the operational capabilities and the characteristics of the nozzle flow of the Seoul National University Hypersonic Shock Tunnel (SHyST), a recently added facility designed to produce high enthalpy flows reaching 4.1 MJ/kg through hypersonic contoured nozzles. Within this investigation, emphasis is placed on the design and utilization of a high spatial resolution pitot rake, serving as an essential instrument for quantifying pressure and Mach number distributions throughout the test section. The experimental results confirm the presence of axis-symmetric behavior and spatial-temporal uniformity of the freestream Mach number at the nozzle outlet and along the test section. Furthermore, the study demonstrates an excellent agreement with the predictions of numerical simulation.

Speaker: Jinyoung KIM
Jinyoung Kim is a Ph.D. student in Aerospace Propulsion Laboratory, Seoul National University.

HiSST 2024 - 103

Numerical Performance Assessment of Vitiated Air Heater for DCSC Test Facility by 3D LES

Bu-Kyeng SUNG, Seung-Min JEONG, Min-Su KIM, Jeong-Yeol CHOI

Pusan National University (PNU), Korea

To better understand the combustion characteristics of a vitiated air heater (VAH) in a direct-connect supersonic combustor, we conducted a Large Eddy Simulation (LES) using the 'reactingFoam' solver from OpenFOAM. The VAH comprised a GH_2/GO_2 single coaxial shear injector for heat addition, surrounded by 24 air injectors for air supply and film cooling. The combustor wall could be thermally insulated by introducing coolant injection and additionally, the turbulent motion could be promoted in the combustion zone. The combustion process completed within the initial one-third length of the combustor, results in a uniform total temperature distribution that aligns with the intended adiabatic flame temperature.

Speaker: Bu-Kyeng Sung
Bu-Kyeng Sung is a Ph.D. Student of Rocket Propulsion Laboratory(RPL) at Pusan National University, Korea. Bu-Kyeng has studied the supersonic nozzle design and the design and simulation of the vitiated air heater of the present presentation. Currently, he is working on the numerical simulation of tangential mode rocket combustion instability.

HiSST 2024 - 260

Development of Millimeter Wave Plasma Interferometry for the Measurement of Precursor Electron Density

Yosuke KUROSAKA, Kohei SHIMAMURA

Tokyo Metropolitan University (TMU), Japan

In this study, a 28 GHz millimeter-wave interferometer was constructed to measure precursor electron number density. Measurements were made using a 9 m long free-piston driven expansion tube. Air was used as the test gas. The electron number density corresponding to the precursor in front of the strong shock wave was generated behind the shock wave at about 3 km/s. Measurements were made using an expansion wave tube. A Teflon window was attached to the observation section of the expansion wave tube and a transmitter/receiver antenna was installed so as to pass through the observation section. Microwaves were focused to a diameter of 50.1 mm using a dielectric lens to increase the spatial resolution of the interferometer. The transmitter and receiver antennas were horn antennas. The electron number density behind the shock wave with a shock wave velocity of 3.58 km/s was obtained as 3.43 × 1018 m−3 .

Speaker: Yosuke KUROSAKA
Kurosaka is a first-year master's student at Tokyo Metropolitan University, Japan. he mainly conducts experiments with Expansion Tubes.

HiSST 2024 - 075

Force Measurement in Shock Tunnel Tests Based on Deep Learning

Shaojun NIE, Yunpeng WANG

Institute of Mechanics, Chinese Academy of Sciences (IMCAS), China

The aerodynamic force measurement conducted within shock tunnels bear paramount technological significance in the field of high-temperature aerodynamics. When a force test is conducted in a shock tunnel, vibration of the Force Measurement System (FMS) is excited under the strong flow impact, and it cannot be attenuated rapidly within the extremely short test duration of milliseconds order. The output signal of the force balance is coupled with the aerodynamic force and the inertial vibration. This interference can result in inaccurate force measurements, which can negatively impact the accuracy of the test results. To eliminate inertial vibration interference from the output signal, proposed here is a dynamic calibration modelling method for a FMS based on deep learning. The signal is processed using an intelligent Recurrent Neural Network (RNN) model in the time domain and an intelligent Convolutional Neural Network (CNN) model in the frequency domain. Results processed with the intelligent models show that the inertial vibration characteristics of the FMS can be identified efficiently. After processed by the intelligent models, high-precision aerodynamic force signals are obtained. Furthermore, the intelligent model method is applied to force measurement with the cone calibration model in shock tunnels. When compared with results from the force measurement database for the cone model, the relative deviation is less than 2%, validating the feasibility of applying deep learning methods in pulse-type shock tunnel balance force tests. The deep integration of deep learning with pulse tunnel force tests is of paramount significance in enhancing performance metrics for hypersonic aerodynamics tests. This exploratory research will also further propel the intelligent development of force measurement in shock tunnels.

Speaker: Shaojun NIE
I am a PhD candidate (currently studying), and my research direction is balance and aerodynamic force measurement experiments in shock tunnels.

Testing & Evaluation 5 (T&E 5)

Chairs: Prof. Vincent WHEATLEY (The University of Queensland, Australia), Dr. Ajmal MOHAMED (ONERA, France)

HiSST 2024 - 259

Design of a Nozzle for Hypersonic Wind Tunnel with Optimized Hyperbolic Geometry

Masaki IIDA, Kohei SHIMAMURA

Tokyo Metropolitan University (TMU), Japan

An expansion tube is a type of shock tube that can generate a high enthalpy flow simulating atmospheric entry. However, hypersonic flows have the problem that the diameter of the test flow becomes smaller due to significant boundary layer development. We designed a nozzle with a contour shape based on the hyperbolic equation to suppress the development of the boundary layer. We obtained the geometry of a hyperbolic nozzle using an optimization algorithm and evaluated its performance using CFD. Then we discussed the design method of the nozzle using multi-objective optimization with genetic algorithm.

Speaker: Masaki IIDA
Affiliation and Position: Tokyo Metropolitan University
Education and Degree: Graduate Student, Engineering degree

HiSST 2024 - 377

Development of Neuromorphic Imaging Spectroscopy for Hypersonic Flight Observation

Tamara SOPEK, Fabian ZANDER, Byrenn BIRCH, David BUTTSWORTH

University of Southern Queensland (UniSQ), Australia

Enhanced capability to collect vital hypersonic flight data is required to better understand the physics of the flow around spacecraft entering Earth's atmosphere. Using novel, bio-inspired cameras will allow spectral measurements to be performed equally well during the day and night without modifications to instrumentation, overcoming the current major limitation of daytime tests. Combining these cameras with high resolution spectroscopy enables more reliable collection of critical data, such as temperature and species composition from the flow around spacecraft on re-entry. Measurements were performed using a novel neuromorphic spectroscopy system and a range of light sources. Acquired data show that both broadband and line spectra were obtained. The present work demonstrates, for the first time, that a spectroscopy system set up based around neuromorphic technology is capable of measuring emission spectra. These results present a landmark first step in developing advanced spectroscopy diagnostics for hypersonic flight observation, such as observations of Earth re-entry missions.

Speaker: Tamara SOPEK
Dr. Tamara Sopek is a Vice-Chancellor's Postdoctoral Research Fellow for Women in STEMM at the University of Southern Queensland

HiSST 2024 - 068

Establishment of Free Piston Type Expansion Tunnel

Honhar GUPTA, Jithin SREEKUMAR, Mohammed Ibrahim SUGARNO

Indian Institute of Technology Kanpur (IIT Kanpur), India

In response to the growing need of ground test facilities for flow conditions corresponding to re-entry of spacecraft in the planetary atmosphere, a Free Piston Type Hypersonic Expansion Tunnel is being established at Hypersonic Experimental Aerodynamic Laboratory at IIT Kanpur. Expansion tunnel is an impulse facility that uses enthalpy increment phenomenon of unsteady expansion. Free Piston Type Expansion Tunnel is 25.2 m long and has nozzle exit diameter of 0.2 m. Test time vary according to flow conditions but are order of 50 microseconds. Computational tools, high frequency static and pitot pressure measurements using PCB pressure transducer, Flow visualization using Schlieren technique, Temperature measurement and species determination using Emission Spectroscopy are utilized for characterization of flow conditions during test time. This facility is designed for stagnation enthalpies upto 40 MJ/Kg and flow velocity upto 8 km/s. The present work is in progress. Further details will be presented in conference.

Speaker: Honhar GUPTA
I, Honhar Gupta, am a PhD scholar in Aerospace Engineering at Indian Institute of Technology, Kanpur, India. I am currently working on Radiation in High Enthalpy Hypersonic flow.

HiSST 2024 - 225

Development of a Free Jet Test Facility Aiming at Preliminary Validating Aeropropulsive Balance Prediction Methodology for Hypersonic Airbreathing Vehicles

Francois FALEMPIN, Alexandra DUARTE ANTONIO, Maxime LECHEVALLIER, Quentin MOULY, Julien LEFIEUX, Etienne CHOQUET, Quentin CHANZY

MBDA, France

In order to validate a trustable methodology to predict the aero-propulsive balance of an air breathing vehicle at high Mach number, MBDA developed a large scale free jet test facility allowing to test a full scale flight experimental vehicle in conditions as close as possible to those encountered in actual flight. Taking benefit of the flight vehicle capability to autonomously operate, the link between the vehicle and its support is limited to 4 piezoelectric gages allowing to directly measure the aero-propulsive balance while performing a variation of injected fuel to air ratio. Several runs have been performed in various test conditions. Test sequence and obtained test conditions for one of these runs, performed in conditions representative to Mach 6 flight, are presented. During the test, the flight vehicle operated properly while the aero-propulsive balance measurement system provided useful test data. It has been possible to measure the aero-propulsive balance along the flow axis during all the test sequence through no-combustion condition, ignition at low fuel-to-oxygen equivalence ratio and then progressively increasing fuel-to-oxygen ratio up to very rich conditions. Numerical simulations have been performed for different fuel-to-oxygen ratio by using some experimental data to define relevant boundary conditions. Such numerical simulations show a very good agreement with test data. For example, for a fuel-to-oxygen ratio equal to one, aero-propulsive balance discrepancy between simulation and test is smaller than aero-propulsive balance variation corresponding to +/- 2.5 percent of fuel-to-oxygen ratio. Such results, obtained in conditions very close to the actual flight ones, confirm the capability of numerical simulation to accurately predict the in-flight aero-propulsive balance.

Speaker: Francois FALEMPIN
Chief Engineer for Hypersonic programs at MBDA up to 2023. Today Executive Technical Advisor. 14 years at

ONERA then 27 years at MBDA

HiSST 2024 - 276

Multi-Temperature Modelling of High-Enthalpy T4 Shock Tunnel Nozzle Flows

Robert WATT, Rowan GOLLAN, Nicholas GIBBONS

The University of Queensland (UQ), Australia

The thermal non-equilibrium state of the gas at the exit of shock tunnel nozzles can have a significant effect on the flow over the test article. The most common modeling of thermal non-equilibrium for hypersonic nozzle flows represents the non-equilibrium state using two temperatures: one for the translation and rotation; and one for the average vibrational energy of all the molecules. In this paper, we extend this model to account for a vibration temperature for each molecule, and compare to the more common approach of using two temperatures. Simulation of nozzle flows of conditions in the T4 shock tunnel facility was conducted using the extended multi-temperature model. It was found that the individual molecular vibration temperatures could vary from the two temperature model. For example, NO was found to relax significantly faster than N2 and O2 in all the conditions considered. The effect could be important for comparing against measurements of individual molecular temperatures, but the overall effect on the gas dynamics is small.

Speaker: Robert WATT
I am a PhD student at the University of Queensland, focussing on simulation of high temperature, non equilibrium hypersonic flows.

Operations and Environment 1 (O&E 1)

Chairs: Prof. Jeong-Yeol CHOI (Pusan National University, Korea), Ms. Valeria BORIO (Politecnico di Torino, Italy)

HiSST 2024 - 116

A Contribution to Mitigate NOx and H2O Emissions for a Hydrogen-powered Hypersonic Vehicle

Daniel BODMER[1], Jacob JÄSCHKE[1], Florian LINKE[2], Volker GOLLNICK[1]

[1]Hamburg University of Technology (TUHH), Germany
[2]German Aerospace Center (DLR), Germany

Hypersonic transport fueled with liquid hydrogen (LH2-HST) is currently considered as long-term future technology of civil aviation to fly with speeds greater than Mach 5 at stratospheric altitudes of 25-38 km. In this paper, we present a comprehensive methodology to assess the emission mitigation potential (via NOx and H2O) of future LH2-HST through operational measures, considering realistic constraints such as the sonic boom carpet as well as tolerable g-forces acting on the passengers while flying with hypersonic speeds. Both NOx- and H2O-optimal 4D-trajectories are identified by a brute-force algorithm that varies the initial cruise altitude from 30 km to 36 km. As case study, the Mach 8 passenger aircraft STRATOFLY-MR3, which was conceptually developed in the framework of the H2020 STRATOFLY project, is operated on a single route from Brussels (BRU) to Sydney (MYA). The findings are highlighted as relative changes regarding MR3's design flight altitude set at 32 km, respectively 105 000 ft. As scientific contribution, 3D emission inventories are calculated and made publicly available for a world fleet of MR3 aircraft operated along the BRU-MYA route on both NOx- and H2O-optimal mission profiles in the year 2075.

Speaker: Daniel BODMER
Daniel Bodmer (m) was born on 03 October 1991 in Ludwigsburg, Baden-Württemberg. He received his diploma (M.Sc.) in mechanical engineering from the Technical University of Munich in 2018 and has been employed as a research assistant at the Institute of Air Transportation Systems (ILT-TUHH) in Hamburg since 2019. As a part of the EU project STRATOFLY, he investigated the impact of civil hypersonic flight operations with regard to the mitigation potential of stratospheric HST-emissions, which will also be the topic of his presentation today.

HiSST 2024 - 344

Analytical Formulations for NOx Emissions Prediction of a SABRE Engine

Fabrizio BORGNA[1], Valeria BORIO[1], Roberta FUSARO[1], Nicole VIOLA[1], Guido SACCONE[2]

[1]Politecnico di Torino, Italy
[2]Centro Italiano Ricerche Aerospaziali (CIRA), Italy

With an expected global revenue exceeding 1 trillion USD by 2040, the space industry is one of the world's fastest-growing sectors. Given the booming investment in the space industry and the anticipated space tourism era, it is crucial to assess the impact of already operative launch assets as well as to adopt design-to-sustainability strategies for the under-development and future launchers. This paper discloses novel analytical formulations to estimate nitrogen oxides emissions of a hydrogen-fueled air-breathing concept using a Synergetic Air Breathing Rocket Engine technology. Benefitting of 0D chemical-kinetic air/hydrogen combustion numerical simulations and related high-fidelity emissive database representative of various on-ground and in-flight operative conditions, the paper formulates novel analytical formulations to extend the prediction capability towards high-speed engines and hydrogen fuel. Throughout the paper, the Skylon spaceplane and its Synergetic Air Breathing Rocket Engine are used as case study. The methodology disclosed allows proving the high competitiveness of this air-breathing space launchers with respect to famous past and current competitors, as the Space Shuttle and the Falcon 9.

Speaker: Valeria BORIO
Valeria Borio is a Ph.D. student in Aerospace Engineering at Politecnico di Torino supervised by Professor N. Viola and Dr. R. Fusaro (POLITO), and Dr. G. Rufolo (CIRA). Her research focuses on the development of sustainable space transportation systems.

HiSST 2024 - 360

Methods and Tools for Chemical Emissions Prediction for Space Launchers

Alessio RICCA[1], Valeria BORIO[1], Roberta FUSARO[1], Nicole VIOLA[1], Guido SACCONE[2]

[1]Politecnico di Torino, Italy
[2]Centro Italiano Ricerche Aerospaziali (CIRA), Italy

The present work aims to investigate the methods for estimating the chemical emissions generated by space launchers. After providing an overview of the current scenario of access to space in terms of technology and propellants employed, the work is focused on reviewing the emissions estimation tools available in the literature and on bridging their inherent shortcomings by developing new formulations. As a matter of fact, the majority of the available prediction methods are semi-empirical and they require a great number of input variables, some of which may not be yet known in the early design stage. Therefore, the objective of this analysis is to develop novel emissions estimation formulations for space launchers, building from emissions estimation methods used for other categories of aerospace vehicles.

Speaker: Valeria BORIO
Valeria Borio is a Ph.D. student in Aerospace Engineering at Politecnico di Torino supervised by Professor N. Viola and Dr. R. Fusaro (POLITO), and Dr. G. Rufolo (CIRA). Her research focuses on the development of sustainable space transportation systems.

HiSST 2024 - 108

Scaling Effects on the Ignition Process in a Single-side Expansion Scramjet Combustor

Peiyi LI, Zun CAI, Yanan WANG, Quanqi WANG, Taiyu WANG, Hongbo WANG, Mingbo SUN

National University of Defense Technology (NUDT), China

With the research of scramjet is gradually developed from small scale to larger scale, it is an inevitable requirement to design large-scale engine on the guide of small-scale engine research results according to the law of scale effect. However, the research on the scale effect is mainly based on the steady process of the flow and combustion, little attention has been paid to the unsteady process. In order to investigate the scale effects on the unsteady process, the ignition in three scramjet combustor of different scale were studied with three-dimension numerical simulation. The numerical study is based on a scramjet combustor of single-cavity ethylene-fueled scramjet with single-side expansion. The k-omega SST two-equation turbulence model are used, ignition process was added to the energy equation as an energy deposition term coupled with the finite rate model. Through the establishment of energy deposition ignition model, the detailed simulation of the main parameters affecting the ignition process, such as ignition position, energy and duration, is achieved. Secondly, through the numerical simulation of the three-dimensional ignition process of the cavity combustor with different scales, it is verified that there is an obvious scale effect in the ignition process of the cavity combustor with different scales. Finally, the specific performance law of the scale effect of ignition energy and ignition time on the cavity ignition process is further explored.

Speaker: Peiyi LI
Affiliation and Position: Student
Education and Degree: postgraduate student

Thermal and Energy Management Systems 3 (TEM 3)

Chairs: Prof. Matthew MCGILVRAY (University of Oxford, UK), Dr. Aaron Dexter KOCH (DLR, Germany)

HiSST 2024 - 335

A Boundary Adaptive Sharpening Topology Optimization Method for High Reynolds Number Flow in Regenerative Cooling Structures

Xinlei LI, Kun WU,Xuejun FAN

Institute of Mechanics, Chinese Academy of Sciences (IMCAS), China

For propulsion systems of hypersonic vehicles, an efficient thermal protection system (TPS) is of great significance to ensure the safety and stability of the vehicles. To enhance the heat transfer performance, the fluid-thermal coupled topology optimization (TO) of regenerative cooling structures is researched. The modified Brinkman-Forchheimer equation and k-ε equations are employed in TO's model, which is verified to be effective for high Reynolds number flow. The n-Decane with variable thermos-physical and transport properties is worked as the coolant. The optimization is conducted in a continuous adjoint framework that constructed in OpenFOAM, and a series of optimization cases in terms of various power dissipation constraints are designed. The optimized layouts are then extracted to be further numerically simulated. The results show that the heat transfer performance of the optimized cooling structure is mostly enhanced compared with the conventional cooling structure, and it also shows good performance under other operating conditions.

Speaker: Xinlei LI
I'm a PhD student, and my research direction is about the design and optimization of engine thermal protection system.

HiSST 2024 - 358

The Effect of Sintering Condition on the Properties and Transpiration Cooling Performance of Porous Ni-based Superalloy

Jukyoung SHIN, Junhyeon BAE, Tae Young KIM

Seoul National University of Science and Technology (SeoulTech), Korea

The development of a Thermal Protection System (TPS) is crucial for reusable space vehicles to protect from extremely high temperatures during atmospheric re-entry, caused by air friction and shockwaves leading to adiabatic compression effects. Transpiration cooling involves the use of porous media, allowing the flowing fluid to absorb and evaporate heat, facilitating efficient heat transfer, which provides excellent cooling performance. In this study, porous metal was produced using a powder sintering process with nickel-based superalloy powder. To analyze the transpiration cooling performance depending on physical characteristics such as porosity, permeability, and pore size of the specimens, the physical property changes were examined based on the powder sintering process parameters, such as compaction pressure and sintering temperature. Subsequently, the transpiration cooling performance was evaluated.

Speaker: Jukyoung SHIN
M.S. student Mechanical Engineering, Seoul National Univ. of Science and Technology B.S. Mechanical Engineering, Seoul National Univ. of Science and Technology.

HiSST 2024 - 067

Experimental Investigation of Film Cooling Effectiveness using Different Coolant Gases in Hypersonic Flows

Jithin SREEKUMAR, Talluri VAMSIKRISHNA, Honhar GUPTA, Mohammed Ibrahim SUGARNO

Indian Institute of Technology Kanpur (IIT Kanpur), India

An experimental investigation has been conducted to study the effectiveness of film cooling on convective and radiative heat transfer at the stagnation point of a body traveling at hypersonic speeds. A simple, flat-faced cylinder has been selected as the model. A provision for attaching an optical fiber cable to collect radiation data was made near the center of the flat face. Thermocouples were strategically positioned along radial direction on the model's flat face to assess the convective heat transfer rates. An orifice, located at the center of the flat face, serves as the point for injecting coolant gas. Two different gases nitrogen and carbon dioxide, are used as coolant gases. Coolant gas injection, whether using carbon dioxide or nitrogen, resulted in reduced convective heat transfer rates compared to scenarios without coolant injection, with lighter gas offering superior cooling. The emission spectroscopy technique was utilized to study the radiation occurring at the stagnation point of the model. Radiation data showed emission lines arising from various contaminant species present in the shock tunnel facility.

Speaker: Jithin SREEKUMAR

Myself Jithin Sreekumar, Ph.D. student at the Indian Institute of Technology Kanpur in the Department of Aerospace Engineering. I completed bachelor's in Mechanical Engineering and joined for direct Ph.D. program at the Indian Institute of Technology Kanpur. My research topic is Experimental investigation into the effectiveness of film cooling on radiative heat transfer in hypersonic flows.

HiSST 2024 - 357

An Experimental Investigation on Geometry Type of Microchannel Heat Sinks to Ensure Flow Stability of Boiling Heat Transfer

Taeho CHOI, Tae Young KIM

Seoul National University of Science and Technology (SeoulTech), Korea

In the space industry, the management of high heat flux is paramount to ensuring the stability and efficiency of equipment operating in the extreme conditions of space. The ability to effectively dissipate heat generated by onboard electronics is crucial for maintaining operational reliability and preventing overheating, which can lead to performance degradation, reduced lifespan, and mission failure. Within this context, the application of multi-phase heat transfer methodologies has emerged as a promising candidate. Specifically, flow boiling within microchannel heat sinks is regarded as a forefront solution to this challenge, attributed to its superior heat transfer performances. Nevertheless, the rapid vapor expansion within such channels frequently incites flow instabilities, manifesting as significant pressure drop oscillations, which pose a substantial barrier to the reliable application of this technology. This research introduces a pioneering solution to address the aforementioned instability through the development of a Half-range T-shaped channel (HRTC). This innovative design incorporates T-shaped flow paths in the upstream portion and V-shaped grooves in the downstream portion, aiming to attenuate the multiphase flow instabilities inherent to conventional systems. The empirical evidence presented within this study illustrates that the HRTC configuration achieves a substantial diminution in pressure oscillation amplitude, surpassing the performance of traditional T-shaped and plate-fin microchannels by more than fivefold under specified conditions of the heat flux of 63 kW/m2 and the mass flux of 200 kg/m2 s.

Speaker: Taeho CHOI

PhD student Mechanical Engineering, Seoul National Univ. of Science and Technology M.S. Mechanical

Engineering, Seoul National Univ. of Science and Technology B.S. Mechanical System Engineering, Jeonbuk National Univ.

HiSST 2024 - 313

Effectiveness-NTU Model for PCM-Compact Heat Exchanger Performance Prediction

Julie FRANK[1], Duncan BORMAN[1], Amirul KHAN[1], Evaldas GREICIUNAS[2], Jon SUMMERS[1,3]

[1]University of Leeds, UK
[2]Ignitis, Lithuania
[3]Research Institutes of Sweden (RISE), Sweden

One of the limiting factors for the development of future aircraft is the size of thermal management systems. The addition of Phase Change Materials (PCM) heat exchangers has been identified as a potential improvement to the system, where the PCM heat exchanger would help in reducing peaks in the heat load, extending the lifetime of current technologies. There is a current lack of low computational cost models suited for the initial sizing phase of PCM-Compact heat exchangers. An effectiveness-NTU model has been developed that tracks the melting/solidification front of the PCM by using a linear approximation of the Stefan Condition. Based on an initial loading profile characteristic of aerospace applications, the model is applied to a PCM-Compact heat exchanger. The model results are in good agreement with three-dimensional CFD results that are used for comparison and achieve a clear reduction in the simulation time from multiple hours to seconds per loading case when comparing the model to CFD simulations.

Speaker: Julie FRANK
I am a current PhD Student at the University of Leeds in the Centre of Doctoral Training of Fluid Dynamics focussing on the implementation of Phase Change Materials (PCM) in Thermal Management Systems (TMS) for aircraft.

HiSST 2024 - 107

Study of Liquid-vapor Phase Change Process inside Porous Cooling Device for Hypersonic Vehicle

Rui MA, Shibin LI, Zhongwei WANG, Lin WANG, Lei ZHANG

National University of Defense Technology (UNDT), China

Aiming at the thermal control problem of the key parts in hypersonic vehicle, an adsorption autonomous cooling device based on porous media was designed. The transient behavior of two-phase flow and heat transfer inside porous media was studied numerically and experimentally in this paper. The two-phase mixing model was used in the numerical method and verified by the visualization experiment. The results shows that the heat transfer performance of adsorption autonomous cooling device was more significant under the hot-end exhaust design. It shows that the temperature of cold-end was still within 100 °C at 1500 s. Moreover, the motion direction of the vapor phase was always opposite to gravity, and the flow direction of the liquid phase was squeezed by the vapor phase and related to the outlet position. The liquid working fluid was more strongly bound by the pore structure. Furthermore, the liquid working medium was further vaporized near the interface after the formation of the two-phase mixing zone.

Speaker: Rui MA
Rui MA, Study of liquid-vapor phase change process inside porous cooling device for hypersonic vehicle. She is a doctor candidate at the Hypersonic Technology Laboratory, National University of Defense Technology.

High-Speed Aerodynamics and Aerothermodynamics 11 (HSA 11)

Chairs: Dr. Chris JAMES (The University of Queensland, Australia), Dr. Minkwan KIM (University of Southampton, UK)

HiSST 2024 - 305

Evaluation of the particle-based Bhatnagar-Gross-Krook method in hypersonic non-equilibrium flows

Woonghwi PARK, Eunji JUN

Korea Advanced Institute of Science and Technology (KAIST), Korea

In hypersonic flows, non-equilibrium flow characteristics are present. To accurately understand such flows, it is essential to obtain the velocity distribution function using a stochastic approach. In this study, the accuracy of the particle-based Bhatnagar-Gross-Krook (BGK) method in the analysis of the velocity distribution function is evaluated in comparison to the Direct Simulation Monte Carlo method. In particular, deviations from the Maxwellian distribution are identified in the velocity distribution function under non-equilibrium flow conditions, and differences in how different BGK models represent this are highlighted. As a result, the Shakhov BGK model is found to be more accurate in reproducing the velocity distribution function than the ellipsoidal-statistical BGK model.

Speaker: Woonghwi PARK

Mr. Woonghwi PARK is a Graduate Student at the Department of Aerospace Engineering, Korea Advanced Institute of Science and Technology.

HiSST 2024 - 209

Numerical Study on the SWBLI Induced Flow Unsteadiness Characterization in a Hypersonic Backward Facing Step

Vignesh P, Mohammad Ibrahim SUGRANO

Indian Institute of Technology Kanpur (IIT Kanpur), India

Shock Wave Boundary Layer Interaction (SWBLI) is inevitable in the case of supersonic and hypersonic flows. SWBLI is typically encountered in the intake of Scramjet inlet and isolator, vehicle surface geometry changes, control surface deflections, at the junction of body-wing of aircraft, etc. For BFS, the dynamics of the SWBLI region and the associated unsteadiness are available only for supersonic Mach numbers, to the best of our knowledge. This study will involve understanding the flow physics under different Hypersonic Mach numbers of 4 and 6. The free stream conditions used for this study including the free stream Mach number, pressure, and temperature correspond to the S1 Hypersonic facility (Ludwieg tunnel) at Hypersonic Experimental Aerodynamics Laboratory (HEAL) at the Indian Institute of Technology, Kanpur. The SWBLI region over a BFS consists of a boundary layer undergoing rapid expansion, Separation bubble, lip shock-reattachment shock interaction, shock shear layer interaction, etc. The aim is to study and characterize the SWBLI region and associated flow unsteadiness over a BFS configuration in a hypersonic flow. The effect of Reynolds number and step height on flow unsteadiness and its influence on the downstream flow field will also be studied. Work is in progress and the numerical results will be presented.

Speaker: Vignesh P

This is P Vignesh, currently pursuing M Tech degree in aerodynamics at Indian Institute of Technology Kanpur, India. I'm performing a numerical study on the SWBLI induced flow unsteadiness characterization in a hypersonic backward facing step.

HiSST 2024 - 258

High-Fidelity Aerothermoelastic Analysis of Hypersonic Vehicle using Fluid Solid Interface

Muhammad Danyal KAILANI, Naveed AHMED, Hafiz Sana Ullah BUTT

CESAT, Pakistan

Area of aerothermoelastic analysis of hypersonic vehicles faces the challenges of coupled interaction between aerodynamics, heat transfer, and structural dynamics. This study presents a novel approach for conducting a high-fidelity aerothermoelastic analysis of hypersonic vehicles utilizing a Fluid-Solid Interface (FSI) framework. The FSI framework allows for a seamless integration of computational fluid dynamics (CFD) and computational structural mechanics and accounts for the dynamic coupling between the high-speed flow-field and the structural deformation of the vehicle; providing a more comprehensive and accurate representation of its behavior. Key components of the analysis include the CFD simulations to compute aerodynamic forces and heat transfer effects and couple them with flexible structure for modal analysis and evaluation. The results of this research offer insights into the complex interplay between fluid and solid domains in hypersonic flight; facilitating the development of more robust and efficient hypersonic vehicles. The FSI-based approach presented in this study showcases its potential to enhance the accuracy and reliability of aerothermoelastic analyses.

Speaker: Naveed AHMED

High-Speed Aerodynamics and Aerothermodynamics 12 (HSA 12)

Chairs: Dr. Nicholas GIBBONS (The University of Queensland, Australia)

HiSST 2024 - 045

Shock Wave Structure and Surface Pressure Prediction using Deep Learning Model

Min Hyun HAN, Soo Hyung PARK

Konkuk University, Korea

Obtaining aerodynamic data through wind tunnel tests or CFD calculations requires substantial human, temporal, and financial resources. This study proposes an alternative method for acquiring aerodynamic data using AI(artificial intelligence) models. Two AI models were employed to predict two types of aerodynamic data. The first AI model utilized a U-Net to learn and predict the structure of shock waves from input images without flow. The second AI model, based on LeNet, was trained to predict surface pressure of a test model from images with shock waves. The training data included shadowgraph images and surface pressure data from wind tunnel tests. The validation of the AI model was conducted by using images of an arbitrary shape from wind tunnel test models as input and comparing the output with CFD results. This validation process aimed to assess the predictive capability of the AI models on data that were not part of the training set, thus confirming the generalizability of the AI models. The results indicated that the aerodynamic data predicted by the AI models was considered valid when compared to the CFD data.

Speaker: Min Hyun HAN
Min Hyun HAN is a Ph.d student at the Konkuk University.

HiSST 2024 - 307

Particle-based Simulation of Solid Rocket Plume at High Altitude

Yeongho SHIN, Eunji JUN

Korea Advanced Institute of Science and Technology (KAIST), Korea

Solid rocket motors (SRMs) are widely used in military and space missions due to their cost-effectiveness and compact design. However, the design optimization of SRMs poses unique challenges compared to liquid-propellant rockets. One primary concern is the emission of micron-sized alumina particles in the exhaust flow. These particles make up nearly 30% of the total mass flow, significantly affecting the flow properties. The exhaust flow with alumina particles can underexpand and backflow due to the rarefied atmosphere, posing potential risks such as base heating, erosion, and contamination. Understanding the exhaust flow dynamics can lead to more efficient SRM designs, potentially improving the efficiency and reducing operational risks. To simulate the multiscale gas flow with solid particles, this study employs two gas-solid interaction models to consider interphase dynamics. Burt's gas-solid interaction model is utilized for two-phase flow simulation. When Burt's assumption of negligibly small solid particle size breaks down in continuum gas regions, the Gas-Solid Synchronous (GSS) model is used to determine the gas-solid interactions. SRM exhaust flow conditions are based on prior studies, while the free-stream flow conditions are obtained from NRLMSISE-2.0 atmosphere model. The results present the impact of alumina particles on the plume and characteristics of backflowing gas around the SRM at 114km and 183km.

Speaker: Yeongho SHIN
Yeongho SHIN is a graduate student at the department of Aerospace Engineering in KAIST, South Korea.

HiSST 2024 - 048

Comparison of Focker-Planck and CFD simulations of the RFZ-ST2 upper stage

Leo BASOV, Moritz ERTL, Tamas BYKERK

DLR - Deutsches Zentrum für Luft- und Raumfahrt, Germany

We simulate the generic upper stage RFZ-ST2 model with both computational fluid dynamics (CFD) and Fokker-Planck (FP) methods. We use the well established DLR TAU code for the CFD simulations and an in-house FP extension to the Direct Simulation Monte-Carlo (DSMC) code SPARTA. The simulations are done close to the continuum limit. The goal is to validate the models used in the FP implementation versus the well established CFD code and to investigate the limitation of the CFD towards higher Knudsen numbers. To this end, we compare the resulting flow fields and surface distributions of pressure coefficients and heat fluxes between both models. The results agree very well between the models in and around the bow shock. Regions further down stream on the model, especially in areas of strong narrowing in the cross section of the rocket show deviations in the flow field and in the calculated surface heat flux and pressure coefficient. In this regions we expect the computationally more expensive FP model to provide results of higher accuracy. We show that areas of disagreement can be identified using a local Kn number criterion which can be evaluated in post processing from CFD data and used to estimate the quality and validity of the solution. We also use this work to introduce the RFZ-ST2 model, an open source model of a generic upper stage to the high speed aerothermodynamics community.

Speaker: Leo BASOV

Leo Basov is a PhD student at the German Aerospace Center, Institute of Aerodynamics and Flow Technology, Spacecraft Department, Rarefied Flows group. Leo Basov holds a M.Sc. in Aerospace Engineering from Stuttgart University, Germany. After graduation he worked for five years as a research engineer in the industrial context on the development of particle based numerical simulation tools for the modeling of electric propulsion systems for spacecraft. In 2021 Leo Basov started a PhD program in cooperation between the German Aerospace Center and the RWTH Aachen University, Germany. The focus of his research is the modeling of polyatomic gases in thermal and chemical non-equilibrium with applications on nozzle expansion flows, plume-surface interactions as well as hypersonic vehicles.

Propulsion Systems and Components 12 (PSC 12)

Chairs: Dr. Moritz ERTL (DLR, Germany), Dr. Marc FERRIER (ONERA, France)

HiSST 2024 - 295

Eliminating Atomic Oxygen from RST Nozzle Simulations

Tristan VANYAI, Nicholas GIBBONS

The University of Queensland (UQ), Australia

Correctly simulating the chemical composition in a test flow is a critical element of supersonic combustion experiments. Radicals generated in the stagnation region of a reflected shock tunnel could be seen as a key departure from the flow in flight experiments. However, there is evidence that only considering 5 chemical species in air gas models is artificially inflating the inferred concentration of atomic oxygen, O, in these test flows. By including a 6th species, NO2, the concentration of O is decreased by many orders of magnitude at conditions suitable for testing supersonic combustors. This paper presents comparisons between 5- and 6-species air schemes for simulations of nozzles and subsequent combustion experiments, that indicate the importance of including NO2 in reflected shock tunnel nozzle simulations.

Speaker: Tristan VANYAI
Dr Tristan Vanyai's research interests are in the fields of hypersonic propulsion, combustion visualisation and laser diagnostics, using both experiments and numerical simulations. He examines improvements to scramjet combustion through experiments in the T4 Stalker Tunnel using advanced optical techniques.

HiSST 2024 - 341

A Numerical Simulation on the Unsteady Flow in a GCH4-GOx Small Thrust Chamber

Hong Yeong PARK, Yun Hyeong KANG, Chang Han BAE, Jeong Soo KIM

Pukyong National University (PKNU), Korea

A numerical simulation was conducted to scrutinize an uncommon phenomenon which is a stepwise increase of thrust performances in the later part of the combustion under the fuel-rich conditions. The calculation domain was included the nozzle outflow region to minimize the influence of the atmospheric pressure condition. The flow field was analyzed using the RANS (Reynolds-Averaged Navier-Stokes) equation, and a non-adiabatic diffusion flamelet with 21 species and 84 reactions was applied to simulate the flame structure. As a result, the pressure and thrust calculated by the simulations were in good agreement with the experimental ones. However, an abrupt increase of thrust performance observed at the later stage of the experimental combustion duration was not clearly captured in the transient results. This indicates a limitation of the combustion model in calculating of unsteady physics.

Speaker: Hong Yeong PARK
Name: Hong Yeong PARK / Major: Computational Fluid Dynamics with a specific emphasis on the methane propellant combustion. / Degree: Master Candidate in Mechanical Engineering, Pukyong National Univ., Korea.

HiSST 2024 - 218

Mechanisms for Combustion Instability by Micro-Rocket Torch in Scramjet Combustor based on Dynamic Mode Decomposition

Shinichiro OGAWA

Osaka Metropolitan University (OMU), Japan

Combustion instability brings many undesirable features to the scramjet engine. Therefore, it is necessary to clarify the combustion instability for stable running of the scramjet engine. To investigate the forced ignition and combustion instability mechanisms using an enormous quantity of OH* chemiluminescence image data, dynamic mode decomposition (DMD) was the focus of this study. The aim of this study was to clarify the forced ignition and combustion instabilities by the micro-rocket torch installed in the scramjet combustor using the DMD. The DMD was applied to OH* chemiluminescence images measured by our previous supersonic combustion experiments. A supersonic combustion experimental study was conducted on different cavity configurations and different fuel mass flow rates. From the modal analysis, the oscillations based on low-frequencies, which are under 1000 Hz, were formed by injector flame feedback from the fuel and micro-rocket torch and flow fluctuation around the cavity. In the high-frequency regions, the oscillation based on high frequencies in the cavity was formed by the incoming turbulent boundary layer. However, further investigation using numerical fluid analysis is needed to clarify the combustion instability mechanisms at high-frequencies.

Speaker: Shinichiro OGAWA

Shinichiro Ogawa is an Assistant professor in the Department of Aerospace and Marine-System Engineering at Osaka Metropolitan University in Japan. He received a Ph.D in Engineering from the Tohoku university in 2021. His research interests focuse on the ignition and combustion mechanisms in the turbojet engine and scramjet engine.

High-Speed Missions and Vehicles 5 (HSM 5)

Chairs: Prof. Ali GÜLHAN (DLR, Germany), Dr. Antonio VITALE (CIRA, Italy)

HiSST 2024 - 113

Aerothermal Loads Analysis of ReFEx by coupled CFD Calculations

Marius FRANZE, Viola WARTEMANN, C. MERREM, Henning ELSÄSSER, Tobias RUHE, Thino EGGERS, Hendrik WEIHS

German Aerospace Center (DLR), Germany

The Reusability Flight Experiment (ReFEx) is an experimental vehicle, which is developed by the German Aerospace Center (DLR). It simulates the re-entry of a reusable booster stage. After being propelled with a VSB30 rocket to an altitude of about 135 km it will perform an autonomous re-entry. This paper is focused on the analysis of the aerothermal loads. Different approaches are applied for the investigations of the thermal heating: from a very conservative worst-case analysis up to a full-coupled simulation via the DLR CoNF2aS2 tool (Coupled Numerical Fluid Flight Mechanic And Structure Simulation). The trajectory includes the launch as well as re-entry flight phase. The focus of the heating process analysis is on the experimental ReFEx vehicle itself.

Speaker: Viola WARTEMANN
Dr. Viola Wartemann is working as researcher at the German Aerospace Center (DLR) since over 15 years. Besides her studies on hypersonic boundary layer transition and re-entry aerodynamics, she is/was involved in several international European Research Projects as well as DLR projects, like for example the flight experiments: SHEFEX, REFEX, where she is/was responsible for the aerodynamical layout.

HiSST 2024 - 161

Local Surface Inclination Method Calculations for the HEXAFLY-INT Vehicle

Pedro Paulo BATISTA DE ARAUJO[1], Roberto YUJITANAKA[2], Fabio Henrique EUGENIORIBEIRO[2], Andre Carlos FRAILEJUNIOR[2], Angelo PASSARO[2], Lucas GALEMBECK[2], Giannino Ponchio CAMILLO[2], Dermeval CARINHANHA JR[2], Johan STEELANT[3]

[1] Aeronautics Institute of Technology (ITA), Brazil
[2] Institute for Advanced Studies (IAS), Brazil
[3] European Space Agency (EAS-ESTEC), Netherlands

In order to improve the preliminary design of high-speed vehicles, the usage of analytical tools could avoid the necessity of CFD simulations in the early stages, decreasing the decision time once the results have a good agreement with data from CFD or experiments. Here, results obtained from analytical calculations based on the local surface inclination method were compared with CFD data related to the HEXAFLY-INT geometry. Comparing the lift and drag coefficients (CL, CD), the CL presented a well fit with CFD data while CD underestimated the drag. The analytical tool only considers the pressure influence on the drag and lift forces, disregarding the viscous effects. Thus, it is expected that the drag coefficient underestimates the results from CFD. Although CD presents a poor quantity agreement, it behaves similarly to the CFD data.

Speaker: Pedro Paulo BATISTADEARAUJO
Researcher in Hypersonic Airbreathing Propulsion at the Instituto de Estudos Avançados (IEAv), graduate student in Space Sciences and Technology at Instituto Tecnológico de Aeronáutica (ITA), Mechanical Engineering and Master in Aerospace Engineering from Universidade Federal do Rio Grande do Norte (UFRN). I am interested in aerothermodynamics, aerodynamics, heat transfer, computational fluid dynamics, and control systems

HiSST 2024 - 190

Ram-accelerator for Future Low-orbiting Operations

Daniele DI MARTINO[1], Elisa DI PAOLA[1], Vincenzo ALLEGRA[2], Emanuele RUA[3], Abdul R.[4], Phanindra PERI[4], Antonella INGENITO[4], Luana Georgiana STOICA[1], Alessandro DI MARCO[1]

[1]University of Rome, Italy
[2]Thales Alenia Space, Rome, Italy
[3]Power and Electronics Subsystem Engineer Rome, Italy
[4]School of Aerospace Engineering University of Rome “La Sapienza”, Italy

The growing request to access to space by Governments and private companies should be supported by a cheaper access to space; in fact, today the Launch Market is dominated by staged expendable Launch Vehicles with a very high cost per kg of payload (PL) around €20.000/€60.000. Innovative technologies leading to a cheaper cost access to space is the most critical objective for the coming decades. A gun is an attractive alternative to a rocket, because it is simple and reusable and can provide an order-of-magnitude increase in payload fraction. Its disadvantages are also considerable, i.e. the launch vehicle must endure high g loads and the severe heating due to trans-atmospheric flight at hypersonic speed. This paper wants to investigate the feasibility of using the ram accelerator to launch medium-small satellites. The thermally-choked ram accelerator (TCRA) performance as function of the fuel composition, pressure and temperature, the barrel length and the combustion heat release have been investigated. This works show the validity of this system as breakthrough for future space launchers of micro satellite.

Speaker: Antonella INGENITO
Professor of Hybrid Propulsion and New Launch Systems at the School of Aerospace Engineering, Sapienza, University of Rome. Head of the Aerospace Propulsion Laboratory, ASPLab. Since 2006, she has been involved in national and international research projects focusing on hypersonics, particularly in the areas of propulsion, engine and vehicle design, as well as the correlation between ground and flight tests (LAPCAT project). Since 2020, she has been a member of the NATO STO AV T group (Science Technology Organization, Applied Vehicle Technology Panel) and the International Academy of Astronautics (IAA). Professor Ingenito has authored over 90 international publications and a monograph on ramjet engines.

High-Speed Missions and Vehicles 6 (HSM 6)

Chairs: Dr. Luke DOHERTY (University of Oxford, UK), Dr. Martin SIPPEL (DLR-SART, Germany)

HiSST 2024 - 207

The HYPLANE Spaceplane

Gennaro RUSSO, Claudio VOTO

Campania Aerospace District (DAC), Italy

The mid-to-long term perspectives of suborbital hypersonic spaceplanes require the availability of ultra-fast, winged vehicles, characterized by low wing loading, streamlined fuselages, sharp nose and wing leading edges, able to manoeuvre along flight trajectories at small angles of attack. From another point of view, the cost associated with sub-orbital space access flight is strongly conditioned by the still small dimension and uncertainties of its market. Therefore, hypersonic technologies and vehicle design suitable for this market as well as for point-to-point fast transportation can facilitate the endeavour.
The paper has the aim to report the status of the HYPLANE project to date. It is a horizontal take-off and landing Mach 4.5 bizjet-size aerospaceplane conceived by Trans-Tech and University Federico II of Naples and under study within the industrial-academic ecosystem of the Campania Aerospace District (DAC). HYPLANE has the aim to offer very fast suborbital flight for space tourism, microgravity experimentation and training, and also shortening time to connect two distant airports within a door-to-door scenario.

Speaker: Marco Marini
Dr. Marco Marini got his M.Sc. in Aeronautical Engineering and Ph.D in Theoretical and Applied Mechanics at the University of Rome "La Sapienza", respectively in 1990 and 1994. He joined CIRA in 1994, first in the Aerothermodynamics Lab. (1994-2009), then as the Head of Applications and Experimentation in Aerospace Propulsion and Reacting Flows unit (2009-2010) and Head of Combustion Unit in Propulsion Division (2011-2014). Between 2015 to 2020 he was part of the Space Integration Technology Division, and he is currently the Head of Hypersonic Vehicles unit. He has had the technical coordination and the project engineering/project management of several national and international projects in the fields of aerothermodynamics and propulsion. He is author or co-author of about 180 publications and reviewer of several international journals.

HiSST 2024 - 323

Sensitivity Derivatives of a Low-Order Integrated Scramjet Propulsion Model for Gradient-Based Co-Design MDAO

Amir MITTELMAN[1], Kieran MACKLE, [1] Ingo JAHN[2], Rowan GOLLAN[1]

[1]The University of Queensland (UQ), Australia
[2]The University of Southern Queensland (UniSQ), Australia

Scramjet-propelled hypersonic vehicles hold vast promise in improving operational flexibility while also reducing the cost of access to space launch systems. However, the highly coupled nature of their components and subsystems makes the design and optimization of such vehicles challenging. To address such cross-coupled, large-scale design problems, computationally efficient tools and a modular approach are needed for the evaluation of the system objectives (performance) and design sensitives (relationship between performance and design variables). In this work, we adopted the modular design framework approach and demonstrated the feasibility of efficiently yet accurately calculating the vehicle sensitivity matrix by combining quick-to-compute component-level partial derivatives. The propulsion system, up to the combustor exit, for both on- and off-design flight conditions is modeled using the newly developed tool HyperPro. An isentropic sensitivity

calculation was added into the aerodynamic solver PySAGAS for nozzle performance analysis. The system level performance and sensitivity calculations were verified by comparison to an inviscid CFD solver - this showed good accuracy of the modular and isentropic approach. The demonstrated effectiveness and flexibility confirm the potential of this approach for Multi-disciplinary Design Analysis and Optimization (MDAO) when applied to complex aerodynamic and fluid dynamic systems such as scramjet-propelled hypersonic platforms.

Speaker: Amir MITTELMAN
Affiliation and Position: Phd candidate, The Centre for Hypersonics, The University of Queensland
Education and Degree: BSc & MSc in Aerospace Engineering, Thechnion, IIT

Chairs: Prof. Jeong-Yeol CHOI (Pusan National University, Korea)

HiSST 2024 - 168

Experimental Measurements on Tekna"PlasmaSonic" High Enthalpy Ground Testing Facilities using 350 kW ICPT Plasma Torch to Reproduce Re-entry Conditions of Space Vehicles

Yazid LAKAF, Siwen XUE, Eric BOUCHARD

Tekna, France

This paper describes an experimental investigation of plasma jet properties on PlasmaSonic 350 kW Inductively Coupled Plasma Tekna torch designed for experimental studies of aerodynamics heating effect under high enthalpy flow testing of thermal protection system. The ICPT-350 can be operated from 0.3 to 5 bar torch pressure and develops an enthalpy of up to 31 MJ/Kg. Various experimental measurements such us enthalpy, heat flux and sample surface temperature are presented and discussed.

Speaker: Eric BOUCHARD
Eric Bouchard is the product line director for plasma equipments at Tekna INC. He has an extensive experience in the design and instrumentation of plasma wind tunnels.

HiSST 2024 - 251

Calibration of the MBDA-Subdray Hypersonic Wind Tunnel n°5

Alexandra Duarte ANTONIO[1], Quentin MOULY[1], François FALEMPIN[1], Gautier VILMART[2], Christophe BROSSARD[2], P. NICOLAS[2]

[1]MBDA, France,
[2]ONERA, France

Both intrusive and non-intrusive measuring techniques are employed for calibrating a new hypersonic wind tunnel developed by MBDA France in its Bourges-Subdray test centre under the aegis of DGA (French Ministry of Defence). Flow measurements are made in a 1.5 m diameter test section, at a single hypersonic Mach number. Calibration parameters include static and stagnation pressure, static and stagnation temperature, species concentrations, Mach number and flow direction. Intrusive measurements include Pitot-probes, cone-probes and stagnation temperature probes, gathered in a single cooled rake, specially designed by MBDA France for this tunnel. Some numerical simulation, performed later, predicted a large unstart of the test section due to the big obstruction created by the rake. A radical modification of the rake has been studied (suppression of 3 of the 6 arms) and considered for further test. In the meantime, a test run was performed to validate mechanical and thermal behaviour of the rake as well as its functionalities. Prior to that, a Tunable Diode Laser Absorption Spectroscopy (TDLAS) setup, developed at ONERA, was implemented and tested during an initial test run for non-intrusive in situ measurements of water vapour concentration and temperature. Measurement data were successfully obtained and compared with data from RANS simulations performed by MBDA. The comparison exhibits around 10% discrepancy in terms of temperature and water vapour content.

Speaker 1: François FALEMPIN
Chief Engineer for Hypersonic programs at MBDA up to 2023. Today Executive Technical Advisor. 14 years at ONERA then 27 years at MBDA

Speaker 2: Christophe BROSSARD
ONERA, Department of Physics, Instrumentation, Environment and Space, Laser Sources and Metrology Research Unit Research Scientist Doctoral Degree in Energetics from the University of Rouen, France, 1995. Past Occupation: 2001-2017: ONERA, Department of Fundamental and Applied Energetics 1996-2001: post-doc and research assistant at the Propulsion Engineering Research Center, Pennsylvania State University

HiSST 2024 - 092

Laser Ablation Experiment of Aluminum Alloy in Ma6 Air Crossflow

Jian LIN, Xing CHEN, Hongbo LU, Shuai WEN , Haiyan LI

China Academy of Aerospace Aerodynamics (CAAA), China

A system of laser-induced material damage coupled with the cross flow was developed. Laser ablation of aluminum alloys embedded in a flat plate was studied in this system of Mach 6 Air crossflow. Aluminum alloys characteristics from laser irradiation were obtained for the conditions of the air crossflow and the quiescent air. The ablation process on spot irradiated by laser was recorded by high speed camera. Temperature behaviors downstream of ablation spot on flat plate was monitored using infrared thermal camera. Experimental results show that the interaction of the shock wave and boundary layer on the flat promotes the laser ablation, generates a deeper and larger spot, indicating the damaging rate is accelerated by the Mach 6 air crossflow. The little bulge has great influence on downstream inflow, but the condition for transition trend by infrared image is not independent, so we need to do separation test to measure the transition.

Speaker: Jian LIN
Prof. Jian Lin is a professor of the China Academy of Aerospace Aerodynamics in China

Propulsion Systems and Components 13 (PSC 13)

Chairs: Dr. Tim ROOS (TNO, Netherlands), Dr. Ravi PATEL (Eindhoven University of Technology, Netherlands)

HiSST 2024 - 239

Simulation of DC Gliding Arcs for Supersonic Combustion: Influence on O2/H2 Ignition

Ancelin ROCAMORA[1], Fabien THOLIN[1], Aymeric BOURLET[1], Julien LABAUNE[1], Christophe LAUX[2]

[1]ONERA, France
[2]CNRS, France

The scramjet engine has been developed to reach high Mach number flight. However, supersonic combustion is difficult to initiate and sustain in a reasonable engine size. In addition to the cavity, strut or step flame holders, PAC (Plasma-Assisted Combustion) is another possibility to stabilize the combustion. This article is dedicated to a particular plasma technology: the Q-DC (Quasi-Direct Current) gliding arc, which creates high temperature regions at about 10 000 K in the fuel mixing zone. The study is based on an adaptation of S. B. Leonov's PIM (Plasma Injector Module) in a Mach 2 flow. To model PAC, the Navier-Stokes equations with Joule heating and the electric-field are solved by two coupled codes. The restrike phenomenon is taken into account, thanks to a plasma discharge macromodel. The combustion of H2/O2 is modeled by a skeletal 9-species kinetic mechanism. This paper demonstrates the capacity of the electric arc to ignite and maintain combustion in unfavourable conditions.

Speaker: Ancelin ROCAMORA
Ancelin Rocamora is a second-year PhD student at ONERA in France, working on the simulation of plasma assisted combustion.

HiSST 2024 - 194

Simulation of the mixing of a supersonic air flow with a transverse jet under the conditions of pulse-periodic local heating

Aleksandr A. FIRSOV, Luka S. VOLKOV

Joint Institute for High Temperatures of the Russian Academy of Sciences (JIHT RAS), Russian Federation

When a supersonic air flow interacts with a transverse secondary jet injected into this flow through an orifice on a flat wall, a special flow structure is formed. This kind flow has set of technical applications related to fuel combustion; therefore, various approaches to intensifying gas mixing in this type of flow have been proposed and studied. This work is devoted to the approach which implies using electric discharges for pulsed heating of the gas and generating the instabilities in the shear layer at the boundary of the secondary jet. In the software package FlowVision the characteristics of the flow were computed in the absence and presence of pulsed-periodic local heating on the injector windward side. This work demonstrate that pulsed heating can stimulate the formation of perturbations in the shear layer and can lead both to a decrease in the average mixing efficiency and to its increase. Additionally, a validation was performed for the used calculation method (unsteady Reynolds-averaged Navier-Stokes equations with a modified k-ε turbulence model). This work was supported by the Russian Science Foundation, grant № 21-79-10408.

Speaker: Aleksandr A. FIRSOV
Aleksandr A. Firsov, Ph.D. Joint Institute for High Temperatures RAS, Moscow, Russia. Dec 2011 - Ph.D. in «Plasma physics» at Lomonosov Moscow State University, Faculty of Physics. Winner of the Moscow Government Prize for young scientists in 2017 in the field of mathematics, mechanics and computer science. Winner of the competition for the Russian Science Foundation grants (2017 (2 years project) and 2021 (3 years project)).

Hypersonic Fundamentals and History 2 (HFH 2)

Chairs: Prof. Liang WANG (Tsinghua University, China)

HiSST 2024 - 223

Influence of Spanwise Wall-Vibration on Bypass Transition in Hypersonic Boundary Layers

Qinyang SONG[1], Ming DONG[1], Lei ZHAO[2]

[1]Institute of Mechanics, Chinese Academy of Sciences (IMCAS), China
[2]Tianjin University, China

Surface vibration, caused by either the mechanical action or the aeroelasticity, is a typical factor to influence the boundary-layer transition over high-speed flying vehicles. This paper studies the evolution of non-modal perturbations excited by low-frequency freestream vortical disturbances (FSVDs) in hypersonic boundary layers with a spanwise vibrating wall. Under the framework of weakly nonlinear theory, a high-fidelity numerical method based on the harmonic linearized Navier-Stokes equations is developed to describe the boundary-layer response to the interaction of the FSVDs and the wall vibration. When the non-modal perturbations accumulate to finite amplitude, the nonlinear parabolized stability equations (NPSE) are employed to accommodate the nonlinear interaction among different Fourier components, leading to the emergence of the secondary instability and eventually transition to turbulence without the attendance of normal modes. It is found that the wall vibration would enhance the strength of the streaks and the instability property of the secondary instability modes, leading to premature of transition remarkably.

Speaker: Qinyang SONG
Qinyang Song, Research Assistant of Institute of Mechanics, CAS. He received the Master degree in fluid mechanics from Tianjin University. His main research interests include flow instability and boundary-layer transition.

HiSST 2024 - 247

High Performance Wall Heat Flux Surrogate Models for vehicles/capsules design activities and Space Debris ground risk estimation - Review of ONERA recent developments

Ysolde PREVEREAUD

ONERA, France

An accurate determination of the wall heat flux in hypersonic regime is crucial for the design of any space vehicle and mission as well as for space debris survivability analysis. During vehicle pre-design and design phases, as well as space debris atmospheric entry prediction, analytical models are used to quickly estimate wall heat flux levels. Existing models in the open literature are either applicable to specific flow conditions and/or only applicable to a limited number of shapes, and/or depend on local parameters not accessible by engineering approaches. Moreover, even though the models are used within their valid range, a high level of uncertainty is generally associated with such obtained solutions. Thus, ONERA has been developing new surrogate models in hypersonic regime from rarefied to continuum flow conditions to improve its capability to describe trajectory ATD processes with a significant increase of accuracy. The aim of the present paper is a focus on the very last analytical formulations, developed to characterize stagnation point heat flux and 3D wall heat flux distribution levels in various flow regimes for any kind of flying shape.

Speaker: Ysolde PREVEREAUD
Ysolde Prevereaud is a researcher at ONERA the french aerospace Laboratory. She works on aerothermodynamic modeling and simulation of atmospheric reentry.

HiSST 2024 - 052

Asymptotic Analysis of Heat and Mass Transfer Performance of a Microscale Wavy Wall

Zhi-Hui WANG, Hui-Jun GAO

University of Chinese Academy of Sciences (UCAS), China

Real surface of hypersonic vehicles could be rough rather than smooth at different scales, and non-equilibrium heat and mass transfer to rough walls is a critical phenomenon that needs to be evaluated in design of the thermal protection system. Take the wavy wall as a typical example, this paper analyzes the heat and mass transfer performance of a surface with microscale roughness by using the asymptotic methods. Analytical results for the local heat flux and chemical reaction rate increments are derived for different non-equilibrium degrees and wave steepnesses, and the corresponding scaling laws are discussed and validate by data from the direct simulation Monte Carlo method. This theoretical study provides a convenient and practical method to evaluate and correct the chemical reaction–diffusion performance of rough walls, and is potentially useful for development of new numerical and experimental techniques in dealing with the complex boundaries in engineering problems.

Speaker: Zhi-Hui WANG
Zhi-Hui Wang works at School of Engineering Science, University of Chinese Academy of Sciences as a full professor of fluid mechanics. His research interests include theoretical modeling and numerical simulation of hypersonic flow and heat transfer, high-temperature non-equilibrium flow, rarefied gas flow and gas-surface interaction.

NOTE

NOTE

NOTE

NOTE

NOTE

NOTE

NOTE

NOTE

NOTE

NOTE

NOTE


HYUNDAI
Rotem
Creative Innovation
for a Better Future
Mach 5
Hypersonic
Dual Mode Ramjet
Hyunadai Rotem
Firing Test


Changing the Future of Space Mobility
with Hybrid Rocket Technology Solutions
A Small Satellite Launch Service Provider, INNOSPACE
INNOSPACE
www.innospc.com


Seoul ADEX 2025
Seoul International Aerospace & Defense Exhibition
in Seongnam
October 21 - 26, 2025
Seoul Airport
www.seouladex.com

HOST & SPONSORS

Host

Sponsors

2024 HiSST Busan

The 3rd International Conference on
High-Speed Vehicle Science and Technology