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ICAO-IFAR COLLABORATION ON AAM

IBRAHIM YIMER, IFAR CHAIR

12 SEPTEMBER 2023

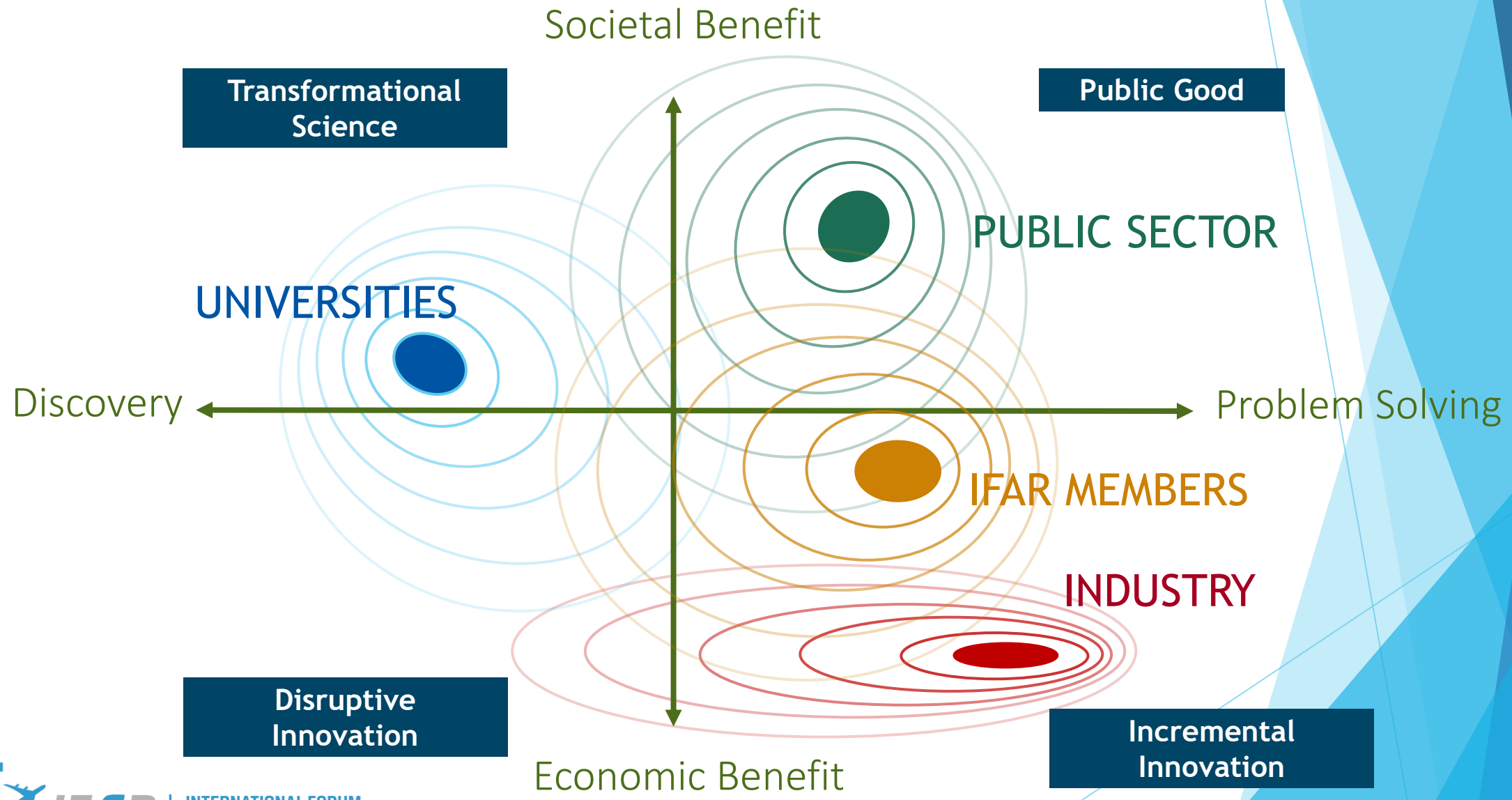
Global Network of Public Aeronautical R&D Institutions

NRC-CNRC
SARC
VTT
CAE
KARI
JAXA
NASA
AEROSPACE TECHNOLOGY INSTITUTE
VON KARMAN INSTITUTE
nlr
DLR
institute of aviation warsaw, since 1926
ONERA THE FRENCH AEROSPACE LAB
TU WIEN
CIRA
MŰEGYETEM 1782
INCAS
CSIR-NAL
CSIRO
IAE
CEiiA
INTA
CSIR
METU
Agency for Science, Technology and Research SINGAPORE

27 countries

40 000 researchers

IFAR REACH



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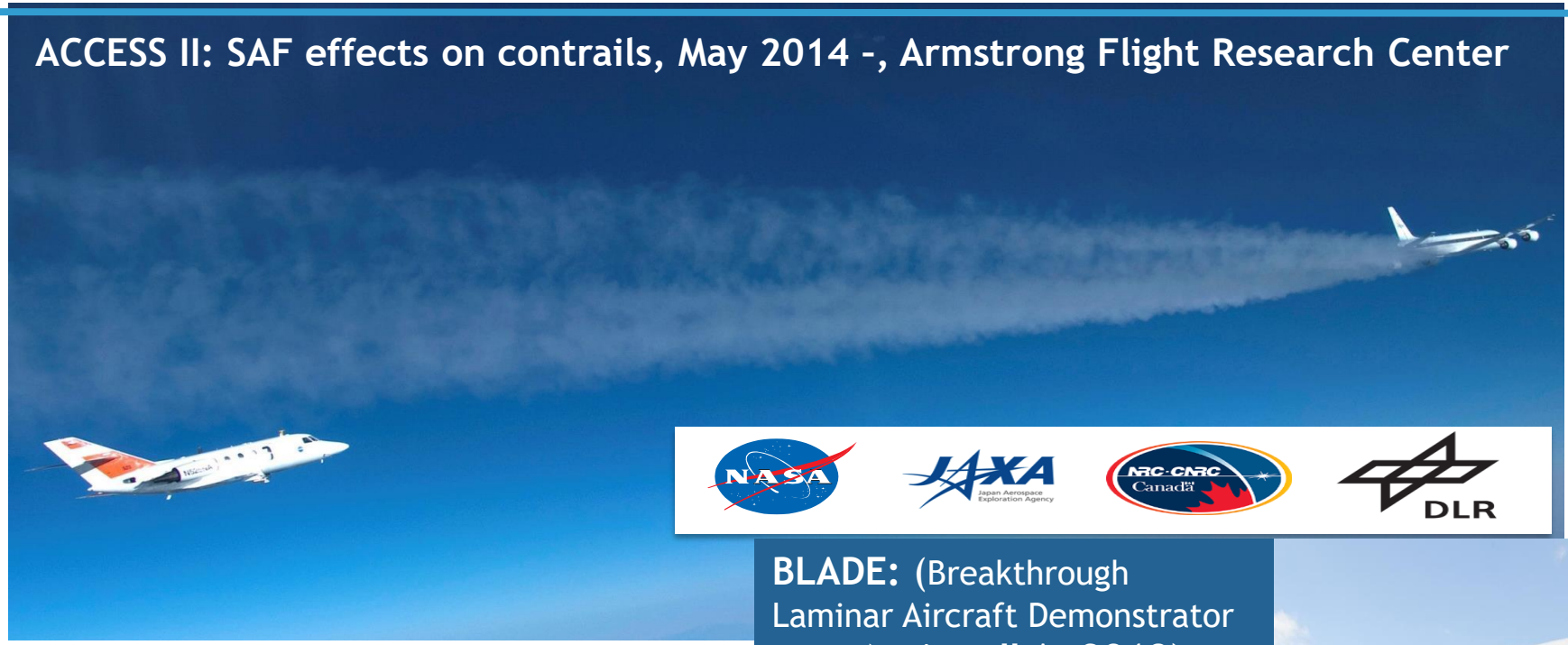
COLLABORATIONS WITHIN IFAR

ACCESS II: SAF effects on contrails, May 2014 -, Armstrong Flight Research Center



BLADE: (Breakthrough Laminar Aircraft Demonstrator for EU) wings **ILA -2018)**

Multiple IFAR members with industry

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CANADIAN VERTICAL LIFT
AUTONOMY DEMONSTRATION

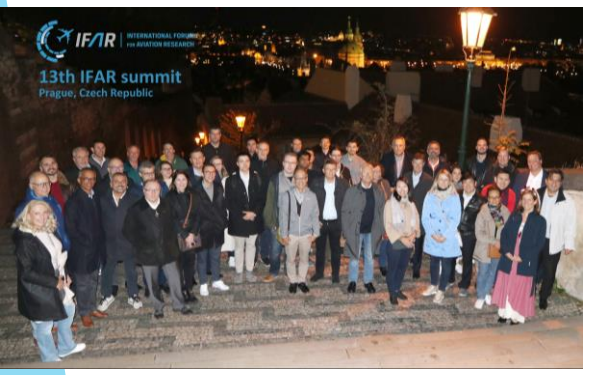
IFAR's Core Activities

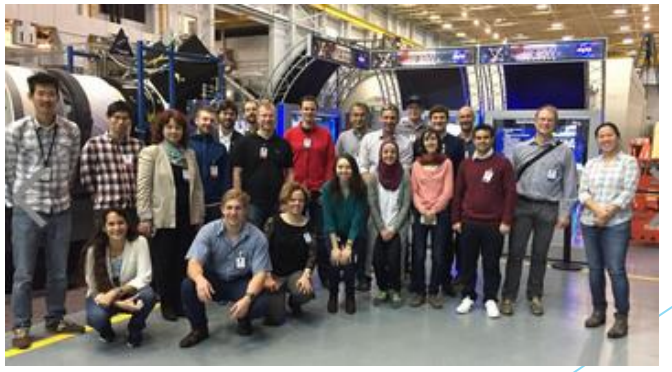
1
Information exchange and networking among the principals at IFAR Summits

2
Technical issues to enable bilateral / multilateral international collaboration

3
Human resources development (empowering early career employees)

4
External partnership
Partners such as:
ICAS (2014)
ICAO (2020)





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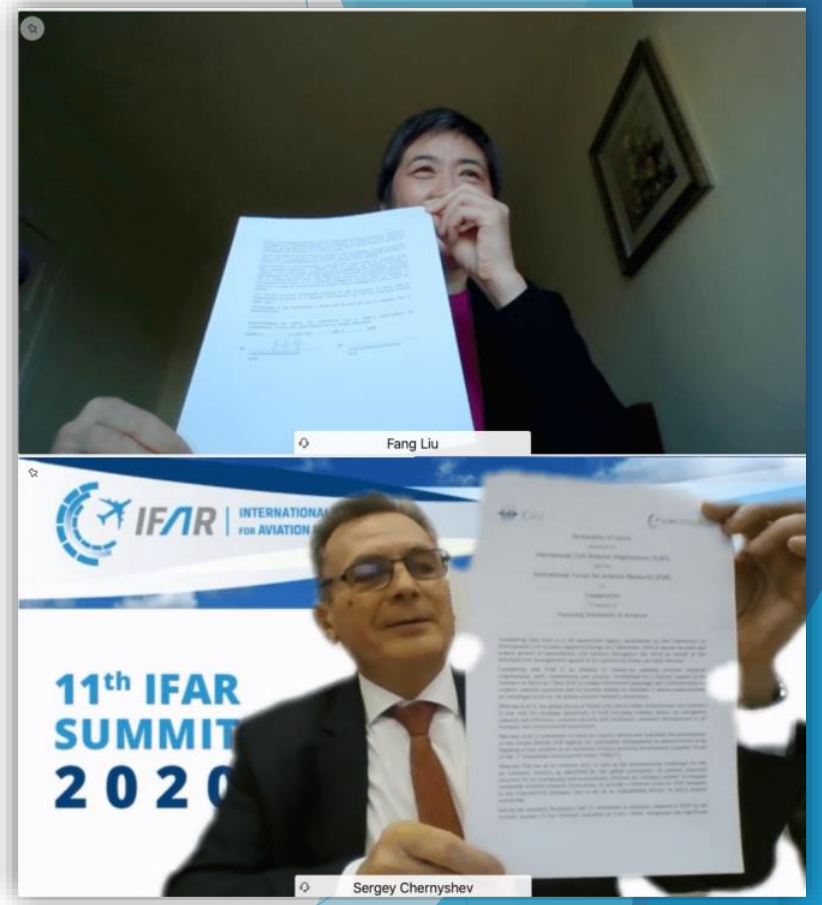
The IFAR-ICAO partnership

… the story so far…

Value propositions for IFAR & ICAO

- ✓ **Foresight to enable innovation**
- ✓ **Technical expertise to inform standards**
- ✓ **Wider international community to disseminate scientific information**
- ✓ **Platform for informing international standards development**



- 8th IFAR Summit, South Africa, 2017: ICAO as a potential partner
- First contact, Feb., 2020
- Invited to a special ICAO Council session, Sept. 2020
- 11th IFAR Summit, Canada, Nov. 2020: Declaration of Intent signed for 2 years

IFAR-ICAO Collaboration

- 12th IFAR Summit, Poland, 2021: Reaffirmed commitments & launched a pathfinder project
- UAM Working group provided an Industry Assessment of UAM
- Special IFAR meeting, Canada, April 2022: MOU signed, with a specialist workshop on Urban Air Mobility
- Expert Group in UAM created with DLR, NASA and NRC as a lead

Objectives Of Working Group / Expert Group

UAM Technical Working Group (WG)

Urban Air Mobility (UAM)

IFAR identified an eminent research demand regarding UAM in three topics:

- Safety standards of vehicles and operations
- Emitted noise during operations

Read more: Urban Air Mobility (UAM)

Urban Air Mobility (UAM) - IFAR.AERO

The purpose of the Working Group is to

- ✓ catalog member activities,
- ✓ facilitate technical partnership opportunities among members, and
- ✓ represent IFAR consensus to external organizations.

IFAR-ICAO UAM Expert Group (EG)

- ✓ review latest innovations in the area of UAM,
- ✓ report back to ICAO and IFAR by providing findings to optimize and formalize IFAR's future contributions to ICAO and international aviation,
- ✓ plan collaboration, define products, define collaboration phases.

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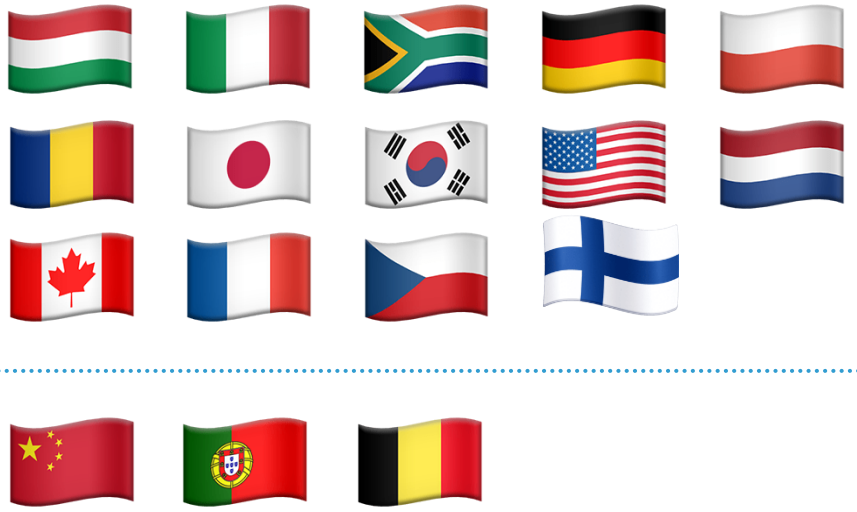
Participating Organizations (WG / EG)

17
Contributing members

80+
Experts

17
Teams



All IFAR members reviewed and endorsed the final assessment report!

1. *BME*
2. *CAE*
3. *CEIIA*
4. *CIRA*
5. *CSIR*
6. ***DLR** **
7. *ILOT*
8. *INCAS*
9. *JAXA*
10. *KARI*
11. ***NASA** **
12. *NLR*
13. ***NRC** **
14. *ONERA*
15. *VKI*
16. *VZLU*
17. *VTT*

** WG / EG leads*

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2¼ year Timeline

2020 Nov. Canada
IFAR-ICAO DoI

2021 January
IFAR UAM EG formed

2021 September
UAM Industry Assessment

2022 April
IFAR-ICAO MOU

2022 July
2nd presentations to ICAO

2022 September
IFAR @ ICAO RPAS Symp.

2022 September
IFAR @ ICAO Innov. Fair

2023 January
3rd Presentations to ICAO

2023 March
Scientific Assessment Delivered

Scientific Assessment on Urban Air Mobility

I. Industry Assessment
II. Technology Area Priorities
III. Operational Area Priorities
IV. Societal Acceptance Area Priorities
V. Standards Landscape

✓Global

✓Independent

✓Research-driven

…achieved by consolidating inputs from individual IFAR members and collaborative consensus on final statements.

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Technology Watch Cards

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2. Propulsion and Energy
Technology Area Overview

Summary of Key Takeaways

Vertical take-off and landing add to energy requirements, and eVToL aircraft can have significantly less range capability than traditional rotorcraft. The major limitation to increased vehicle performance is the gravimetric energy density of batteries compared to liquid hydrocarbon fuels coupled with currently insufficient battery technology to support the high energy discharge rates required for takeoff and landing. Certifying authorities are working to adapt existing rules or adopt new ones where needed. There are many areas that need to be developed for the vehicle and the ground infrastructure to ensure operational safety and the safety of the public.

Overview of Technology Area

To successfully operate in the urban environment, many believe that UAM vehicles must be capable of vertical take-off and landing (VTOL) to operate in small area and the vehicles should not contribute to the emissions problem that is present in most cities. These requirements present unique technical challenges and result in designs for UAM vehicles that are VTOL and use electric or hybrid-based propulsion systems. A critical challenge for UAM market growth is to gain public acceptance for being as safe as - or safer than - commercial air travel or automotive transportation. Vertical take-off and landing add to energy requirements, and aircraft using a large number of propellers are less efficient in hover than traditional rotorcraft. The major limitation to increased vehicle performance is the poor specific energy of batteries compared to liquid hydrocarbon fuels coupled with the need for a high energy discharge rate for hover. Any type of novel refueling/recharge system will require significant investments in technology and infrastructure.

State of the Art Assessment

Electric propulsion systems are operational and in demonstration flight tests in many vehicles. Many advances are needed in the power density, reliability, packaging, monitoring, servicing, and ground infrastructure to advance to scaled commercial operations. Electric motors, no matter the power source, give off low grade thermal heating even in the best of design conditions. Cooling systems for the motors and shedding the excess thermal energy that is generated is a serious design consideration for the vehicles. Hybrid-electric systems can extend the range of the UAM vehicles. Hydrogen fuel cell propulsion systems are proposed as an alternative to increase range but have not been demonstrated. For hydrogen systems, a major limitation is physical space on the vehicle for the fuel cells and storage tanks. The TRL for hydrogen/fuel-cell technology lags battery technology but may be more revolutionary. Neither of these advanced propulsion concepts is currently being used in commercial operations.

Gap Analysis

Battery technology development is needed to increase the specific energy and the charge/discharge rate. Battery improvements are also needed in smart energy storage/management, rapid recharge capability, high-voltage hybrid-electric generators, as well as weight, safety, reliability, cost and other factors. Enabling technologies at the system level are needed to package the batteries for optimum efficiency and safety. Broad updates in infrastructure and economy are needed to enable hydrogen benefits. Also, the net emissions of pure electric aircraft compared to hydrogen fuel cells needs further analysis. Certification requirements for UAM VTOL vehicles are still evolving. Some requirements indicate that components of the propulsion system may require the highest levels of reliability to meet expected safety requirements. Existing UAM vehicle concepts may have a difficult time meeting this high reliability required. Standardization of power system connections and charging infrastructure is needed for scaled operations.

Open Research Areas

1. Are there new motor designs that have higher reliability than current designs?
2. Advanced thermal management systems that are lightweight and work in hover and low-speed flight conditions.
3. Investigation of the mechanical fatigue of motor components (ex: motor windings due to high-cycle thermal loads).
4. Electric components, power distribution, power quality, high voltage systems, motor design, and integrated thermal management systems need further research.

Recent Research Publications

- Highlights of GAO-22-105020, a report to U.S. Congress
- Hazard Analysis Failure Modes, Effects, and Criticality Analysis for NASA
- Design of a Tiltwing Concept Vehicle for Urban Air Mobility
- NASA Reference Motor Designs for Electric Vertical Takeoff and Landing Vehicles

Adapted from: "DRAFT V2 IFAR Scientific Assessment of UAM_prop.docx" and "Key Take Aways Propulsion and Energy Ver 2.pptx"

Moving forward…

- IFAR delivered a high quality Scientific Assessment of IFAR members' perspectives on Urban Air Mobility
- **Presented to the ICAO Council special session on a special session on innovation, March'2023.**
  - IFAR has a new rep on an ICAO Study Group on AAM (May, 2023)
- In the process of selecting the next topic
- *IFAR to become an "Invited Organization to ICAO"*
- This group includes:
  - UN Family Organizations, 25 Intergovernmental Organizations
  - 47 NGOs like Royal Aeronautical Society, IATA
- We receive invitations to participate (no fees)
  - ICAO General Assembly – every 3 years
  - ICAO Council – as needed
  - Committee Meetings – as needed

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Some lessons

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What are the lessons so far?

- As aeronautical innovation accelerates through autonomy, digitization, AI and environmental concerns, regulators are challenged to keep up pace. Added with industry pressures, they are welcoming of unbiased scientific advice from publicly funded scientific organizations.

- We had to reconcile with IFAR members' support to their respective National regulators
  - Our researchers already participate in ICAO technical committees (e.g., CAPE)
  - We had to find the right point of entry → The Office of the Secretary General (SPCP-Strategic Planning, Coordination and Partnerships Office), ANB

- ICAO is a large, consensus based organization that develops regulations (SARPS and PANS) but has no enforcement powers → political sensitivities
  - We had to select the innovation topics of interest carefully
  - The process also helped to have all IFAR members build consensus and fully endorse a scientific document
- Balancing expectations with resource commitments
  - The report required countless hours, all on a volunteer basis covered by IFAR members

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QUESTIONS?

NRC·CNRC

Recent NRC Autonomy Demonstration

Future Vertical Lift's Experimental and Developmental Gateway Event (EDGE)

Yuma, AZ

An Example: Safety Management System

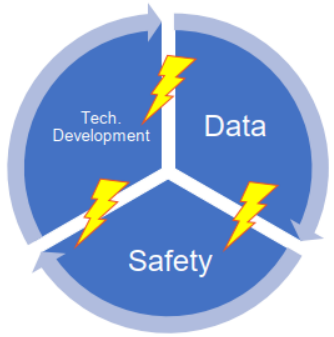
Key Takeaways: Safety Working Group (2/2)

SMS according to Annex 19

- Currently UAM operators and UTM service providers are not considered
- Different requirements in terms of safety and SMS for different technologies / operations? (e.g. risk-based appraoch in analogy to SORA)

Data deficiency for setting up SMS and safety baselines

- Technological data (new technologies and more complex systems)
- Operational data (no operations yet, therefore e.g. no incident data)
- Potentially „vicious cycle“ (Data vs. Safety vs. Technology Development)



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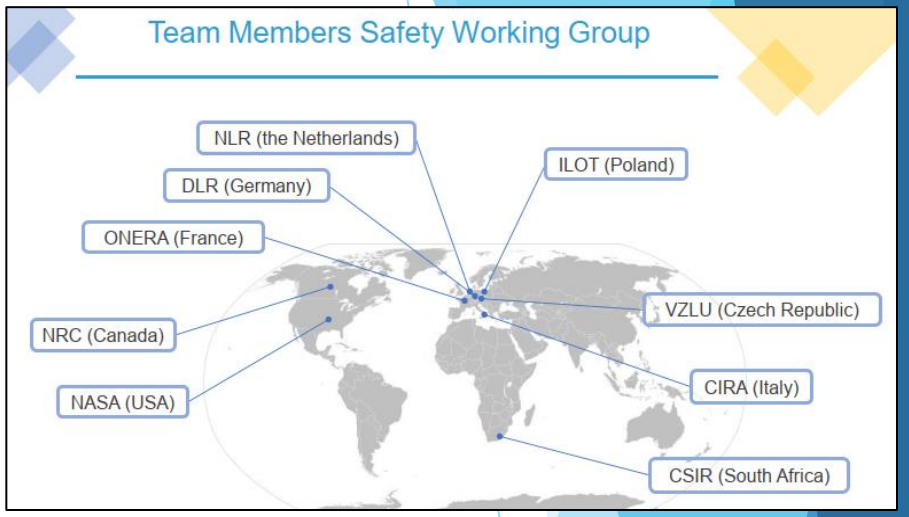

Agreement

- ✓ to launch a collaborative project,
- ✓ build a theoretical SMS for UAM, and
- ✓ assess how it could inform an amendment to Annex 19

Why IFAR?

- ✓ Non-biased insight into UAM/AAM use cases
- ✓ Early feedback on new technologies and processes
- ✓ Experience with new ways of looking at safety

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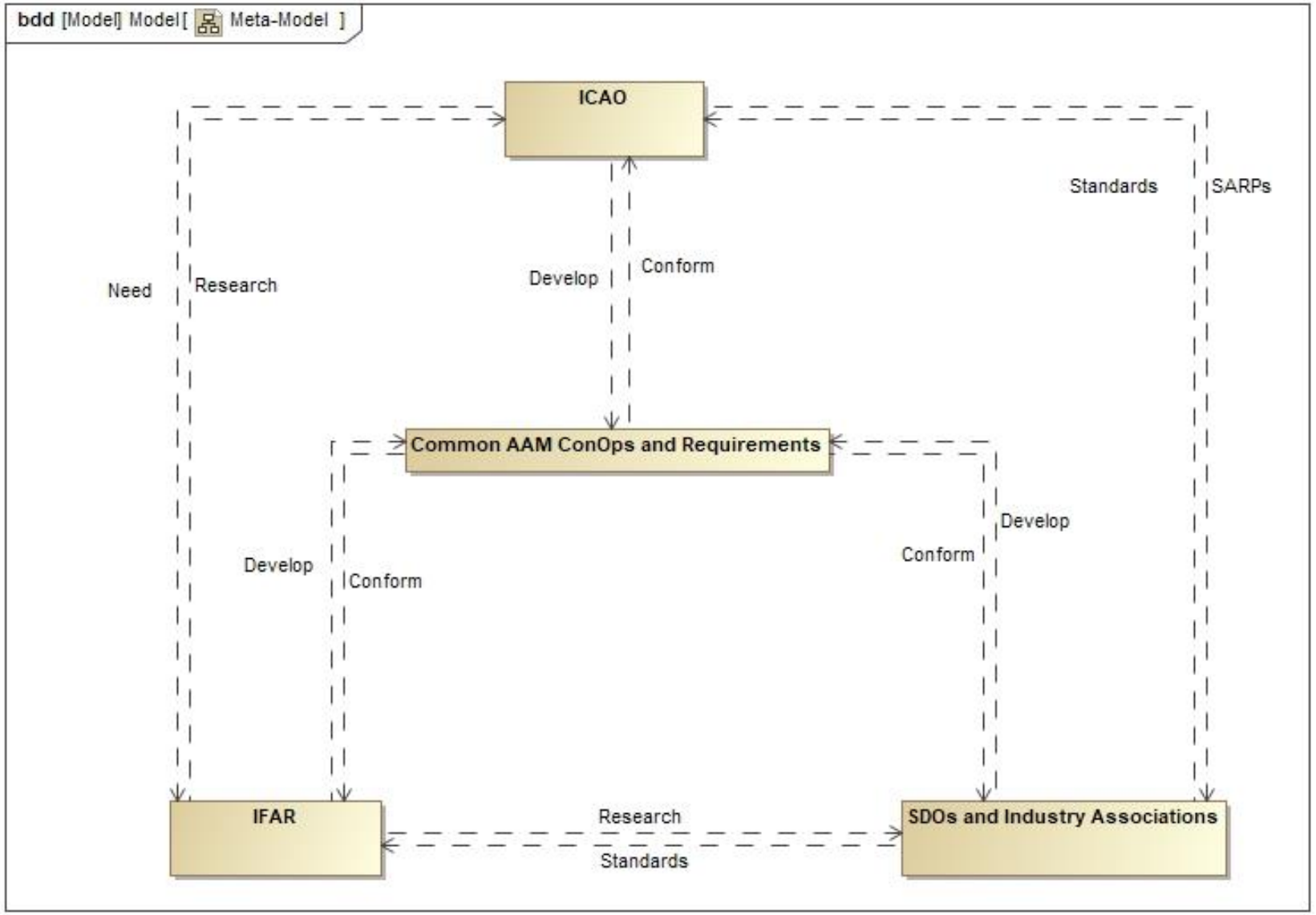
NASA IFAR/ICAO MBSE "META-MODEL"



Model Development Plans:

Model IFAR, ICAO, and SDO structures for analysis

↓

Evaluation and analysis on conops, requirements, architectures, and tech transfer

↓

Integrated use-cases, technology products, and standards common across IFAR R&D organizations

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