National Aeronautics and Space Administration

NASA Advisory Council Aeronautics Committee Report

Mr. John Borghese
Vice Chair
NASA Johnson Space Center
December 2, 2015

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Rolls Royce North America

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- Dr. Karen Thole, *Pennsylvania State University*
- Dr. Lui Sha, *University of Illinois*
- Mr. Stephen Morford, *Pratt and Whitney*

Areas of Interest Explored at Current Meeting

Topics covered at the Aeronautics Committee Meeting held on November 12, 2015 at NASA Headquarters:

- Vertical Lift Project Planning*
- Convergent Aeronautical Solutions Project: An Update*
- Update on University Strategy*
- ARMD Research Data Access Strategy
- Vision and Strategy for Real-time System-wide Safety Assurance
- Summary Report of the UTM Convention*

* These topics have related recommendations or findings provided by the Aeronautics Committee

Vertical Lift Project Planning

Civil Rotorcraft Market Current Outlook

- Civil Market is projected to continue growth over next decade[1]
  - $7.7B in 2015 ⇒ $10.8B in 2020[1]
  - Improvement in global deliveries from 10-22% during 2015-2019[2]
- Near-term – Projections show civil sector sales increasing while military sales are decreasing; value of production about equal in civil vs military sales by 2020
  - Emergency Medical Service operations in new global markets (particularly India, Korea, China, South America)
  - Oil and gas sector, especially long-range off-shore operations; however, oil price reductions are impacting this market outlook and are being carefully tracked
  - Search & rescue, training, firefighting, law enforcement, surveillance
  - Corporate/executive transport/ tourism
- Long-term – Possible new markets will open 5-20 years
  - Autonomous missions (cargo, pipeline patrol, surveillance, etc.)
  - Urban commuter transport
  - Regional passenger service

[1] The World Rotorcraft Market, Vertiflite, Vol. 61, No. 3, 2015
[2] https:// aerospace.honeywell.com/~/media/infographics/HAI_InfoGraphic_FF_2015_P.ashx?la=en

Vertical Lift Project Planning

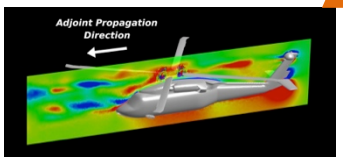
Enhancing Vertical Lift Capabilities

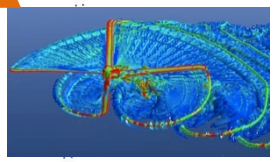
Transformative Concepts

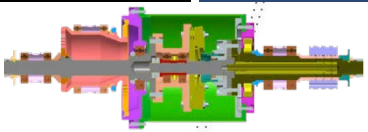
(e.g. hybrid electric, autonomy, new concepts)

FUTURE CAPABILITIES

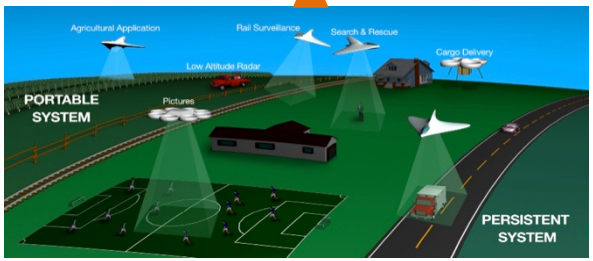
Research focus in Subsonic Rotary Wing and Rotary Wing Projects
(2006–2014)







Revolutionary Vertical Lift Technology Project (2015+)
Innovative technologies, tools & concepts (e.g. low noise, efficient propulsion, & optimization technologies)



Unmanned Traffic Management System

- Key to safely opening new markets
- Important de-confliction with existing vertical flight

Vertical Lift Project Planning

Revolutionary Vertical Lift Technology (RVLT) Project

Develop and Validate Tools, Technologies and Concepts to Overcome Key Barriers for Vertical Lift Vehicles

Vision

- Enable next generation of vertical lift vehicles with aggressive goals for efficiency, noise, and emissions to expand current capabilities and develop new commercial markets

Scope

- Technologies that address noise, speed, mobility, payload, efficiency, environment, safety
- Conventional and non-conventional very light, light, medium, heavy and ultra-heavy vertical lift configurations

Vertical Lift Project Planning

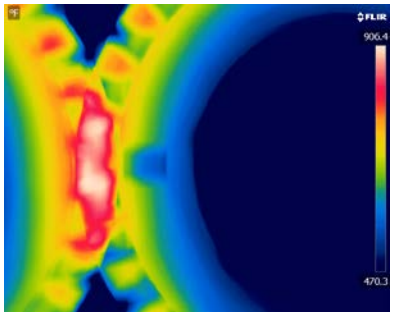
RVLT Research Themes and Tech Challenges

Research Theme	Tech Challenges 2015–2020	Other Research in Theme Area 2015-2020	Addresses
Clean and Efficient Propulsion	**Variable Speed Power Turbine Technology Demo:** Demonstration 50% improvement in efficient operational capability **Two-Speed Drive System Demo:** Demonstrate two-speed drive system with 50% rpm reduction	• High efficiency gas generators • Hybrid electric propulsion • Condition Based Maintenance methods	Speed, mobility, efficiency, environment, payload, noise, safety
Efficient and Quiet Vehicles **Safety, Comfort, Accessibility**	**Technical Challenge:** Demonstration of an MDAO Design Process for Vertical Lift Vehicles (draft) **Technical Challenge:** Design Capability for a Low-Noise Rotor Considering Constraints (draft)	• Internal cabin noise • Crashworthiness • Icing for rotorcraft • Hover performance and prediction • High fidelity CFD modeling and accuracy	Noise, speed, mobility, efficiency, safety, environment, payload

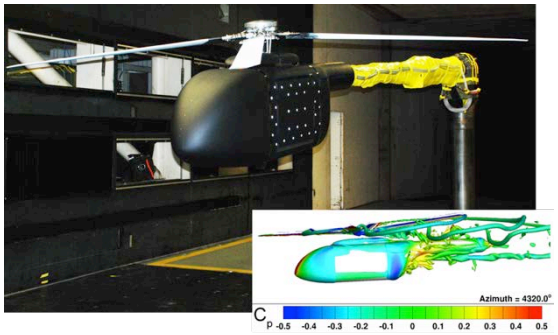
Vertical Lift Project Planning

Vertical Lift Technology Project Summary

- NASA RVLT is focused on overcoming significant barriers to the use of vertical lift vehicles in expanded missions
- Providing technology leadership
  - Technologies to optimize rotor designs for low noise considering other operational constraints
  - Efficient configuration concepts that reduce fuel burn
- Develop vision of the future for vertical lift
  - Technologies to advance innovative concepts

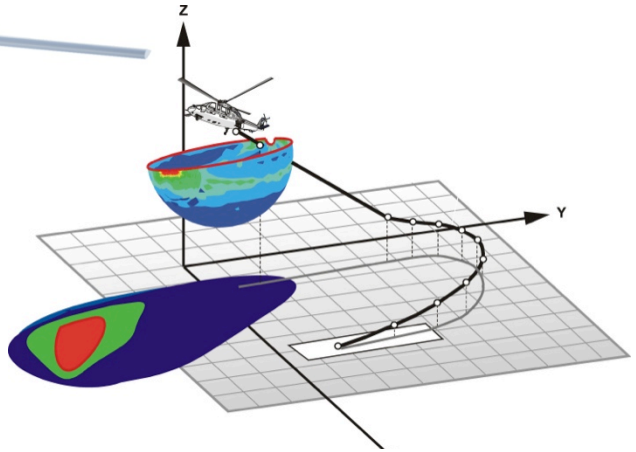


Thermal imaging of gear teeth



Fuselage drag reduction

Conceptual design



Noise Modeling

Committee Finding for ARMD AA on the Vertical Lift Project

The Committee emphasizes that with a limited budget, the project is taking the right path and it's a well thought-out plan. The Committee commended the project in doing a very good job in balancing the portfolio with limited resources.

Convergent Aeronautical Solutions (CAS) Project: An Update

Objective and Characteristics

Convergent

Cross-Discipline, Cross-Center, Diverse Sources

Targeted

CAS Activity

Transformative

Feasibility Assessment Focused

Rapidly Executed

CAS will support, inform, and challenge ARMD strategic decisions by:

Converging emerging and non-aeronautics technology advancements

Rapidly completing concept feasibility assessments to identify boundaries of concept effectiveness, reveal value, and reduce risk.

CAS Project Progress in FY15

- First incubation cycle completed
- Initial activities in execution
  - 3 activities run thru “trial” selection process
- First CASTInG
  - 17 concept proposals
  - 6 activities selected for FY16 execution start
- Investments in collaboration tools and teaming
  - Utilization of FY15 budget augmentation
- Big Question workshops
  - ARMD/TACP-managed, Project support, to collect input and develop BQs
- CAS Showcase

This conceptual art shows the main idea behind the "digital twin" – could a computer model be created that can predict how an aircraft or component will perform over time?

This conceptual art shows the main idea whether a vehicle with electric propulsion could use its structure to serve as a battery.

CAS Research Activities

	Activity
FY 15 Initial Activities	Scalable Convergent Electric Propulsion Technology Operations Research (SCEPTOR)
	Design Environment for Novel Vertical Lift Vehicles (DELIVER)
	X-Plane
FY 16 New Activities	Autonomy Operating System for UAVs (AOS4UAV)
	Digital Twin
	High Voltage Hybrid Electric Propulsion (HVHEP)
	Learn to Fly (L2F)
	Mission Adaptive Digital Composite Aerostructure Technologies (MADCAT)
	Multifunctional Structures for High Energy Lightweight Load-bearing Storage (M-SHELLS)

CAS Activity (Example)

Scalable Convergent Electric Propulsion Technology Operations Research (SCEPTOR)

- Big Question:
  - Can rapid, inexpensive sub-scale technology development and testing show the ability of Distributed Electric Propulsion (DEP) to achieve ultra-high efficiency, low carbon emissions, and low operating costs at high-speed?
- Idea/Concept:
  - Design and fabricate a DEP wing system, retrofit a Tecnam P2006T with a DEP wing, flight test to show the benefit achieved.
- Feasibility Assessment:
  - Establish baseline cruise energy required, apply new technology, determine whether 5x reduction goal is achieved.
- Feasibility Assessment Criteria:
  - Cruise energy required at high-speed (150 knot) cruise.
- ARMD Strategic Thrust: 4, 3

- Objective:
  - SCEPTOR focuses on how DEP technologies enables cruise efficiency at higher speeds.
- Approach:
  - Phase I: Requirements Definition, Systems Analysis, Wing System Design, Design Reviews. Ground validation of DEP high lift system. Flight testing of baseline.
  - Phase II: DEP wing development and fabrication. Ground and flight test validation of electric motors, battery, and instrumentation.
  - Phase III: Flight test electric motors relocated to wing-tips, with DEP wing including nacelles (but no controllers, or folding props).
- Results:
  - Phase I activities nearing completion, including…
    - HEIST/LEAPTech mobile truck 1st generation DEP wing ground testing to validate high lift CFD.
    - Instrumented Tecnam P2006T baseline performance, stability, and pilot proficiency flight testing.
    - DEP wing aero-propulsive, structural and aeroelastic design with upcoming PDR on Nov 12-13.
- Significance:
  - Fully electric General Aviation technology demonstrator with zero in-flight carbon emissions
  - Near-term application pathways to subsonic and vertical lift markets requiring shorter range.

Committee Finding for ARMD AA on the CAS Project

The Committee recognized that this is a very innovative approach that provides an incubation cycle to answer big problems. The Committee was impressed with the innovation and number of ideas that are being pursued in a short amount of time. The Committee endorses the approach laid out by the project and feels that it provides tremendous benefit to the Mission Directorate mission.

Update on University Strategy

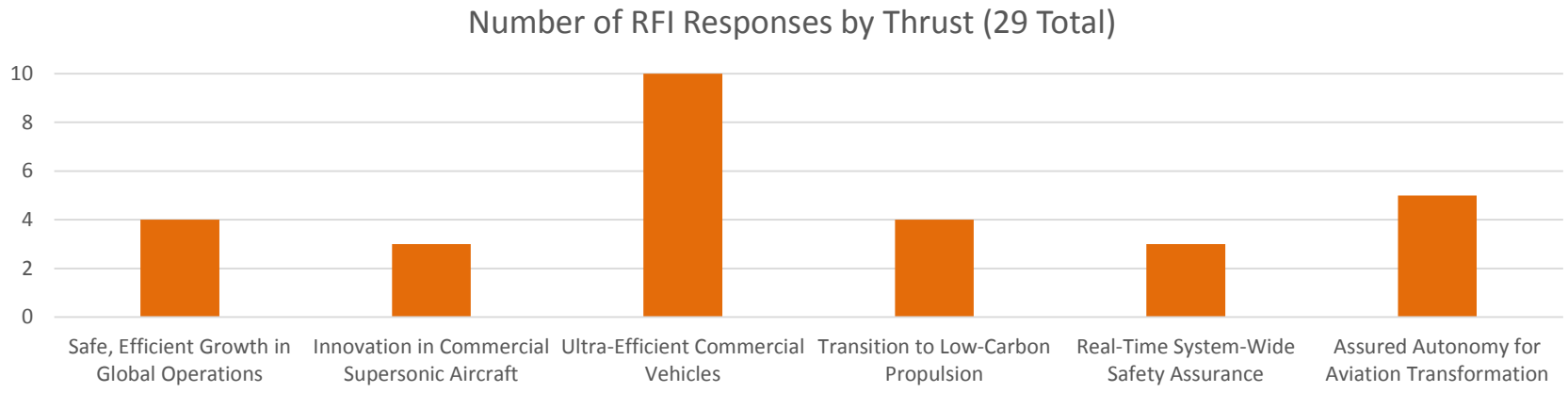
Strategy and Approach

- Create "University Aeronautics Leadership" research initiative to:
  - Help solve most complex challenges associated with strategic thrusts
  - Accelerate progress toward achievement of high impact outcomes
  - Leverage capability of universities to bring together best and brightest minds across many disciplines
- Initiative provides opportunity for universities to exercise leadership and contribute to ARMD in a more strategic manner.
- ARMD plans to release a competitive solicitation
  - Proposals expected from individual universities or university-led partnerships
  - Awards aligned with each ARMD Strategic Thrust (as funding allows)
  - Universities will **propose their own technical challenges to accomplish strategic thrust outcomes, supported by an innovative, multi-disciplinary research portfolio to address those challenges**
  - Universities maintain technical independence and normal peer review, with NASA providing strategic oversight
- ARMD released RFI to university community - responses received end of July

Update on University Strategy

Request for Information (RFI)—Background and Demographics

- Information requested from universities included:
  - Research areas of interest and corresponding ARMD strategic thrust
  - University capabilities and qualifications
  - Current or potential partnerships
  - Areas of suggested clarification for further NASA communication on university-led strategic research
- Received 29 responses from 18 different universities across 14 states



Committee Finding and Recommendation for ARMD AA on the University Strategy

Finding

The Committee applauds ARMD for developing a strategy to encourage Universities to move into a position of leadership to tackle core technical challenges. The Committee found that this strategy showed leadership in this area. Asking Universities to take a leadership role in addressing large ideas is a positive development to utilize their full potential to help shape the future.

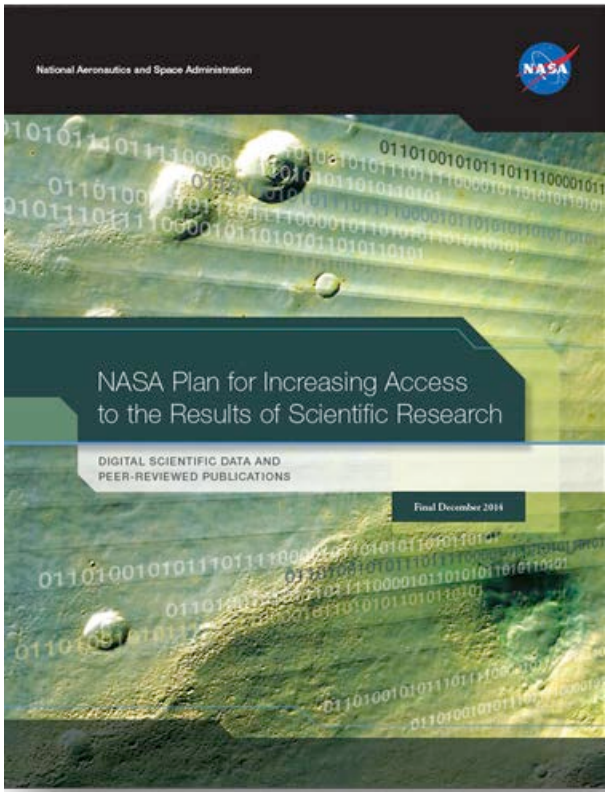
Recommendation

The Committee recommends that the communication with the university community be improved by reaching out early and through multiple channels to insure receiving the broadest possible response. Examples include early indications of intent to release a BAA and early notifications to the research division of institutions to allow appropriate time to generate ideas for proposals.

ARMD Research Data Access Strategy

Motivation

- OSTP Memo from February 2013 directs Federal agencies with over $100 million in research and development expenditures to develop a plan to support increased public access to the results of the funded research.
- The Agency developed the NASA Plan for Increasing Access to the Results of Scientific Research.
- A draft NPD 2230, Research Data and Publication Access is almost finalized.
- The CIO is also developing a data website as a front end for all of NASA data.
- The peer-reviewed publications will be housed in the PubMed Central system.



"Effective data management has the potential to increase the pace of scientific discovery and promote more efficient and effective use of government funding and resources."
(Excerpt from the NASA Plan)

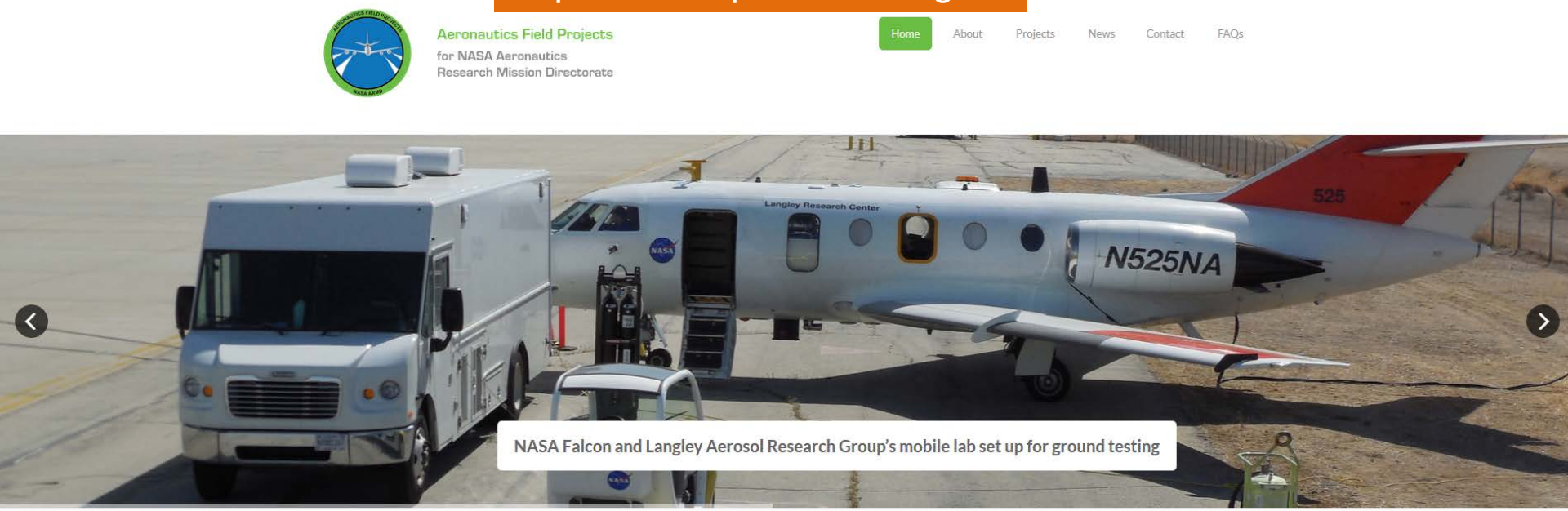
ARMD Data Access Strategy Objectives

- Our goal is to make our data more valuable by making it available to a wider audience than just our formal partners.
- The ARMD guidance addresses both data management and archiving, and publications.
- The ARMD strategy and guidance is in accordance with the NASA Plan and any other policies already in place.

Pilot Project

Documentation: Web Archives

https://aero-fp.larc.nasa.gov/



Went live Aug 11, 2015!!

Will archive data from: EXCAVATE, APEX-1,2&3; AAFEX-I&II, ACCESS-I&II
Located on LaRC DAAC, can host data from all of ARMD's field projects

Pilot Project Dataset

Costs and Lessons Learned

Lessons Learned:

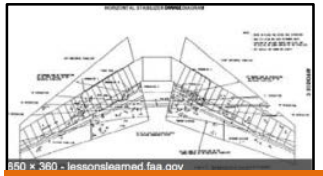
- It is beneficial to have a common data archive capability. ARMD either needs to develop its own or more formally partner with SMD to leverage their investment.
- Initial and continuing costs must be assessed up front.
- Costs associated with ARMD-related efforts may be much larger on a percentage basis (i.e., in comparison to the size of ARMD programs and projects) than SMD-related efforts.
- Overall the process took longer than expected—long reviews for example.
- Organization of the data important to enable users to identify what they need.
- Perhaps it was because this effort had particular attention, but additional Program Staff time was required, which we do not expect to be the case in the future.
- Training is needed. Many researchers are not familiar with new requirements.

Costs:

- Start-up/initial costs ~$80K (full cost including FTE, WYE and contribution to host server)
- Continuing (annual recurring) cost ~$28K (full cost)
- Costs based on leveraging/usage of existing SMD-sponsored server. Establishing/maintaining datasets on other servers may be more expensive.

Vision and Strategy for Real-time System-wide Safety Assurance

Current Safety Assurance Methods







Design | Development | Training | Normal Operations | Off-nominal Situations | Accident or Incident

Requirements | Testing | Best Practices | Standard Procedures | Emergency Procedures | Analysis

Certification Standards

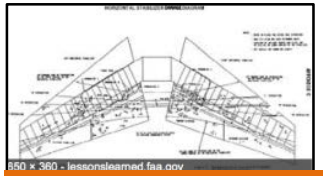
Proficiency Standards

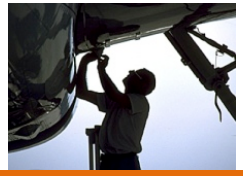
Maintenance

NTSB Recommendations
CAST Safety Enhancements

Vision and Strategy for Real-time System-wide Safety Assurance

Current Safety Assurance Methods




Design | Development | Training | Normal Operations | Off-nominal Situations | Accident or Incident

MITIGATION

Requirements | Testing | Best Practices | Standard Procedures | Emergency Procedures | Analysis

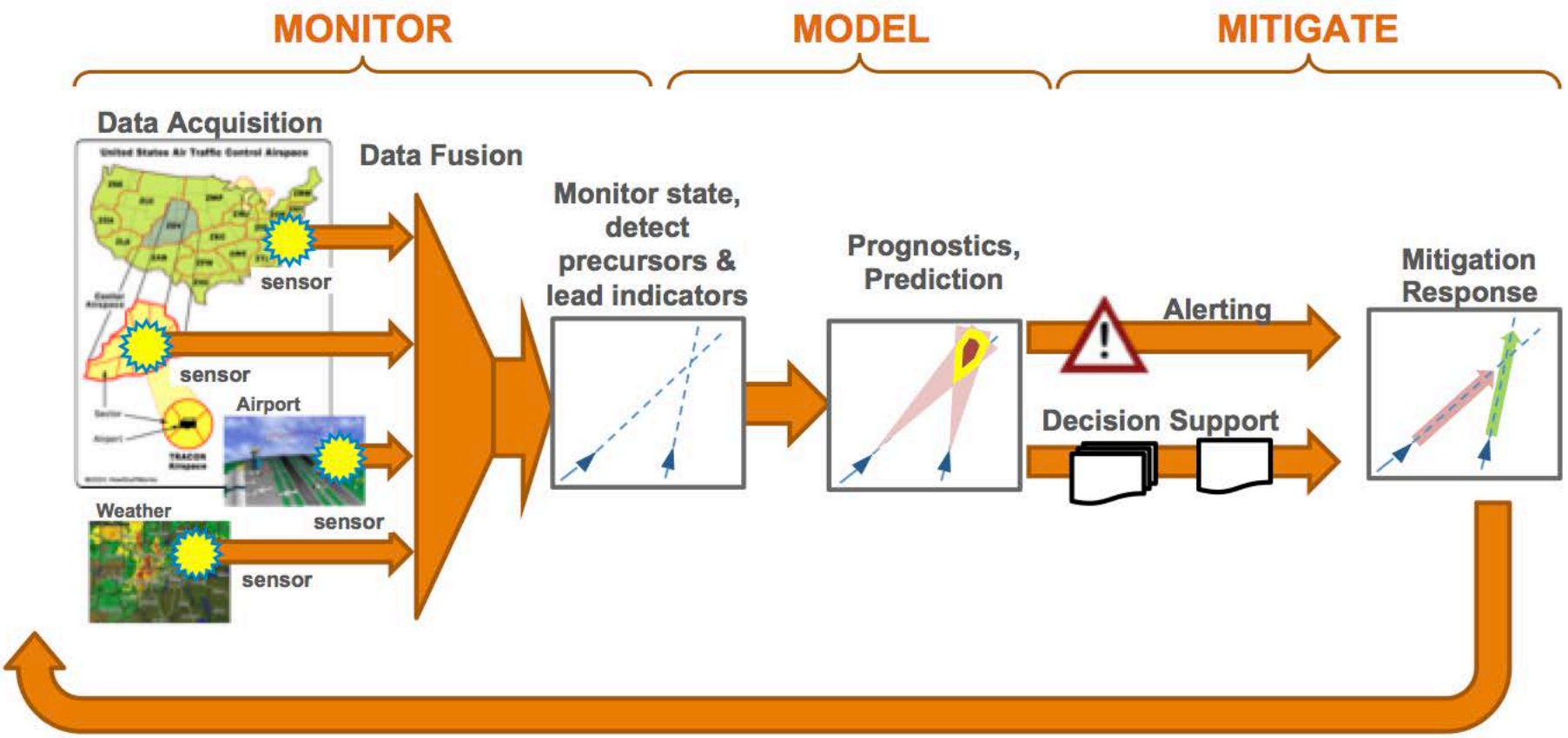
Certification Standards | Proficiency Standards | Maintenance

MONITORING

MODELS

RSSA Functions

RSSA Simplified Vision



Real-time continuous loop:

More Selective Monitoring

Improved Models

Evaluation of Mitigation Strategies

RSSA Outcomes and Benefits

	2015	2025	2035
Outcomes	Domain Specific (Real-time) Safety Monitoring and Alerting Tools	Integrated Predictive Technologies with Domain Level Application	Automated Safety Threat Management
Benefits	Expanded system awareness through increased access to safety relevant data; initial real-time analysis and alerting capability at the domain level	NAS-wide coverage of real-time analysis and alerting; initial integration with mitigation evaluation using decision support tools	Integration of analysis and decision support tools; adaptive human-automation teaming for optimum threat management

Summary Report of the UTM Convention

Unmanned Aerial System Traffic Management (UTM)

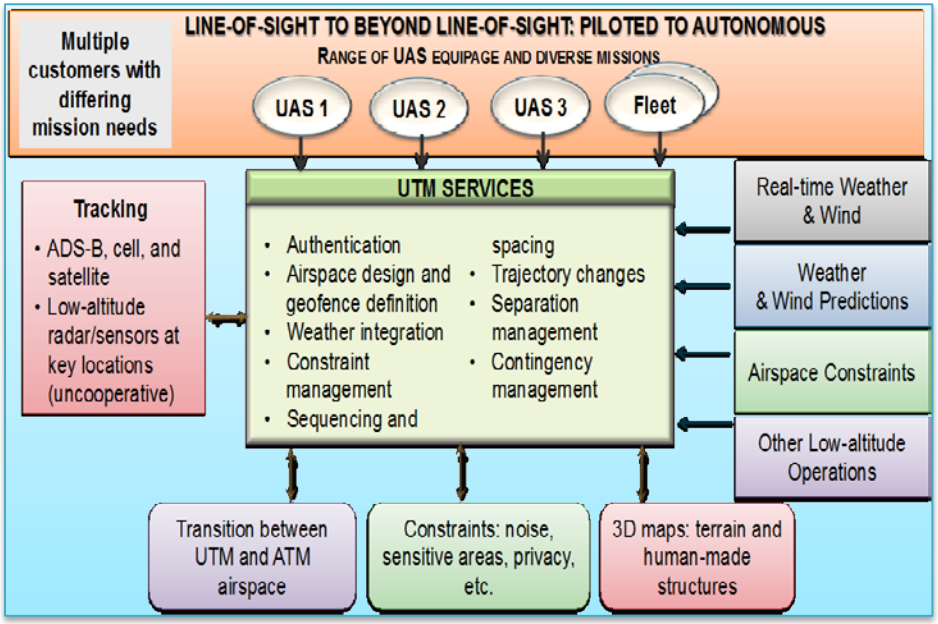
Near-term goal: Safety enable initial low-altitude UAS as early as possible

Long-term goal: Accommodate increased demand with highest safety, efficiency, and capacity

What is UTM?

Research software application prototype that (1) allows UAS operators to submit flight plans to execute a specific mission in low-altitude airspace, and (2) determines how to safely enable such single or multiple UAS operations either within visual line-of-sight or beyond visual line-of-sight

- Allows requester to create and submit one or more trajectories
- Shows all airspace constraints (dynamic and static geo-fences)
- Supports connection to external subsystems (e.g., 3D maps, weather data, etc) through standardized interface protocols
- Assesses and advises for trajectory interference or constraint violations
- Provides multiple trajectories for the same UAS with rank ordering to seek the best available trajectory in presence of other operations and constraints
- Tracks vehicle position and adjusts as needed



Airspace Manager and UAS operators are primary users

Cloud-based user access

UTM: Balancing Multiple Needs

National and Regional Security

Protecting key assets

Safe Airspace Integration

Flexibility where possible and structure where needed

Geographical needs, applications, and performance-based airspace operations

Scalable Operations for Economic Growth

Ever-increasing applications of UAS: Commercial, Agricultural, and Personal

UTM Convention

- Held on campus at NASA Ames Research Center, July 28-20, 2015.
- Discussions with NAC Aero Committee served to inspire creation of the UTM Convention.
- 1,190 Registered attendees – 71 non-US citizens

UTM System/Software Builds

Each build is incremental upon the capabilities of the prior build

BUILD 1 (August 2015)
- Within all visual line-of-sight
- Reservation of airspace volume
- Over unpopulated land or water
- Minimal general aviation traffic in area
- Contingencies handled by UAS pilot
- Enable agriculture, firefighting, infrastructure monitoring

BUILD 2 (October 2016)
- Beyond visual line-of-sight
- Tracking and low density operations
- Sparsely populated areas
- Procedures and “rules-of-the-road”
- Longer range applications

BUILD 3 (January 2018)
- Beyond visual line of sight
- Over moderately populated land
- Some interaction with manned aircraft
- Tracking, V2V, V2UTM and internet connected
- Public safety, limited package delivery

BUILD 4 (March 2019)
- Beyond visual line of sight
- Urban environments, higher density
- Autonomous V2V, internet connected
- Large-scale contingencies mitigation
- News gathering, deliveries, personal use

UTM Convention Summary

- UTM convention was a great success in bringing many stakeholders together: first of its kind with airspace and traffic management as focus
  - Increased awareness of the challenges of managing low-altitude airspace
  - UTM construct has wide spread appeal
- Research and operational issues will be examined as we move forward
  - Open to concept feedback and changes
- Collaborating with FAA and the community to identify research, policy/regulatory steps, and consider integration with existing systems
  - Creating a joint NASA/FAA endeavor to allow us to gather input from the UAS community and build a common research agenda to move more quickly toward safe UAS integration
  - Mechanism to do this is open to discussion
- NASA's goal is to continue to conduct research, development, and testing in close collaboration with FAA and the community to accommodate large-scale demand for broad national benefit

Committee Finding for ARMD AA on the UTM Convention Summary

The Committee found that the briefing was well prepared and clearly stated the goals of the project. The committee was impressed by the effort led by NASA and how the concept is being endorsed by the community both by FAA and industry.