



System Wide Safety

National Aeronautics and
Space Administration



Research and Technology Challenges for Human Data Analysts in Future Safety Management Systems

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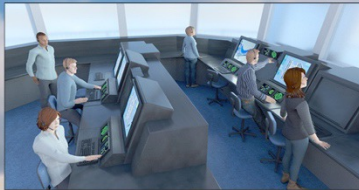
International Symposium on Aviation Psychology - 1 June 2023

Innovating the Future of Aviation Safety

Radar Based

Safety + Density

Human centered traffic & safety management

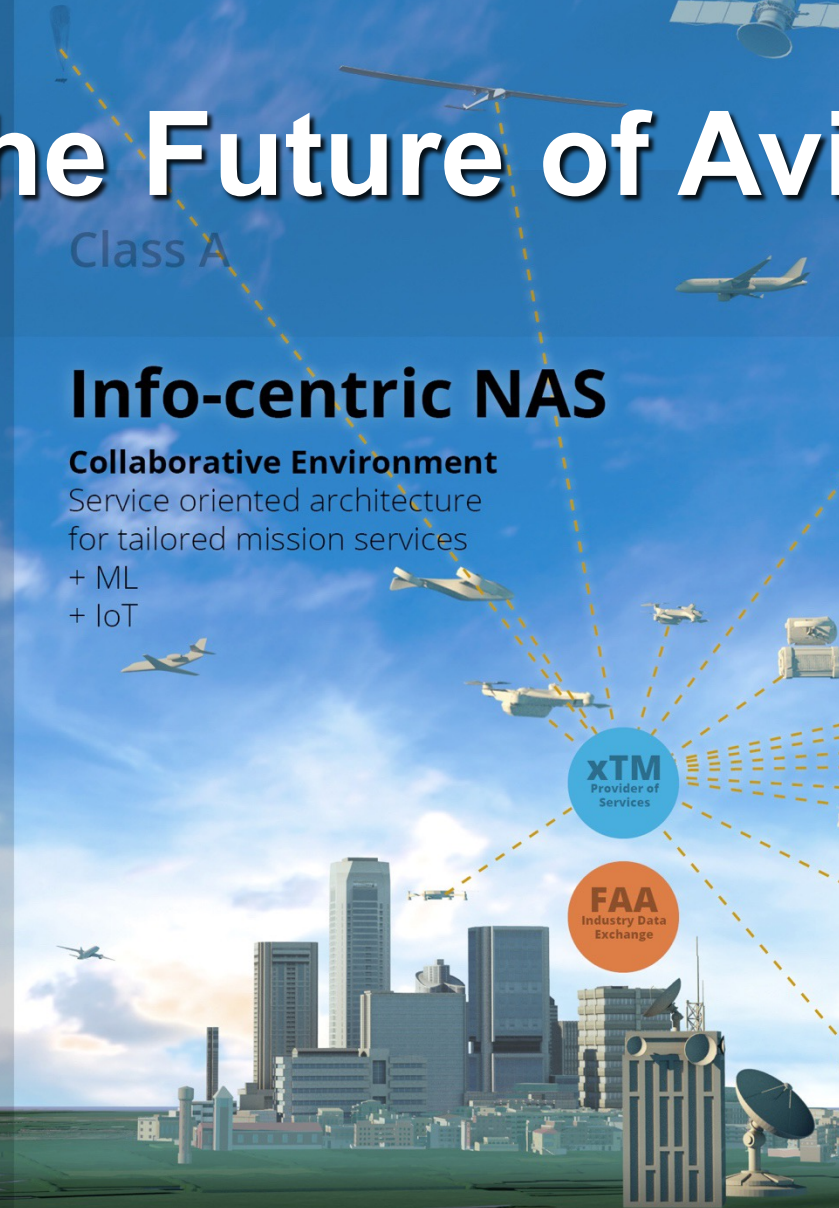


Info-centric NAS

Collaborative Environment

Service oriented architecture for tailored mission services

+ ML
+ IoT

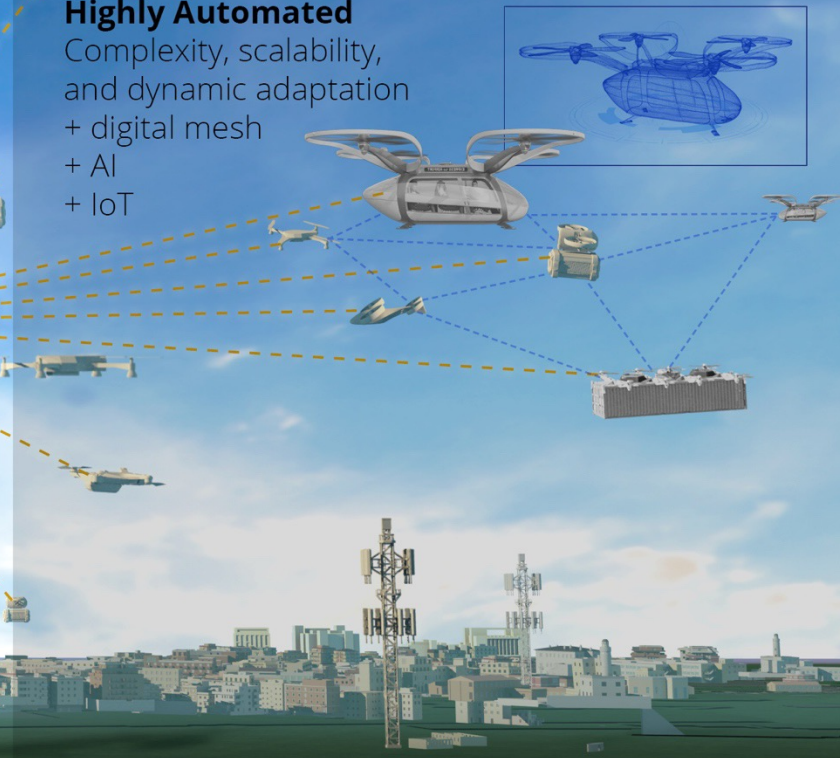


Sky for ALL

Highly Automated

Complexity, scalability, and dynamic adaptation

+ digital mesh
+ AI
+ IoT



Evolution of Airspace Operations and Safety



System-Wide Safety

In-time Safety Needs and Impact

Need: Novel types of aircraft having different performance capabilities and wide complexity of operations necessitates the development of tools and processes to quickly (in-time) mitigate risks and hazards effectively and economically.

Objective: Develop innovative ways for humans to interact with safety data and manage information to rapidly evaluate existing and discover new patterns in data that lead to negative outcomes before the next safety event occurs.

Impact: Improved speed and characterization of system-wide risk identification to augment existing SMS processes supporting risk management and safety assurance.

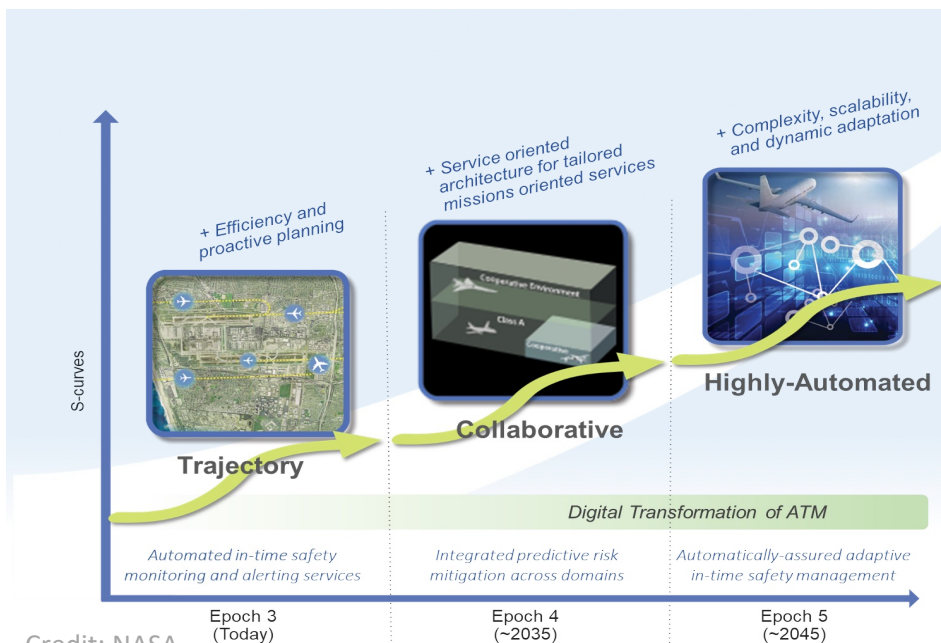
NASA System-Wide Safety Project



- To explore, discover, and understand the impact on safety of growing complexity introduced by modernization aimed at improving the efficiency of flight, the access to airspace, and/or the expansion of services provided by air vehicles.



Credit: NASA



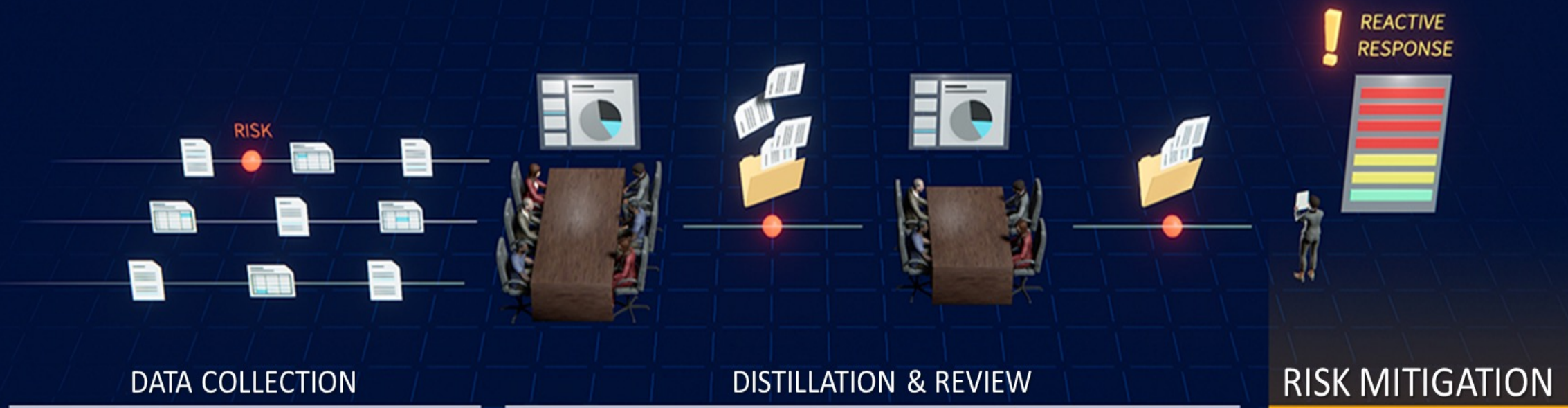
Credit: NASA

- To develop and demonstrate innovative solutions that enable this modernization and the aviation transformation envisioned for global airspace system through proactive mitigation of risks in accordance with target levels of safety.

Current SMS for Air Carrier Operations



SMS



Credit: NASA

Current Safety Intelligence

Unknown Risk



Less Data

Limited Number
of Accidents

Current Numbers
of Everyday Flights

Large Number
of Future Flights

More Data

Data Challenges: The Four V's



➤ Volume:

- Radar Tracks: 47 facilities (1 year) ~423 GB (Compressed), ~3.2 TB (CSV)
- Weather and Forecast (Entire NAS): CIWS ~2.8 TB

➤ Velocity

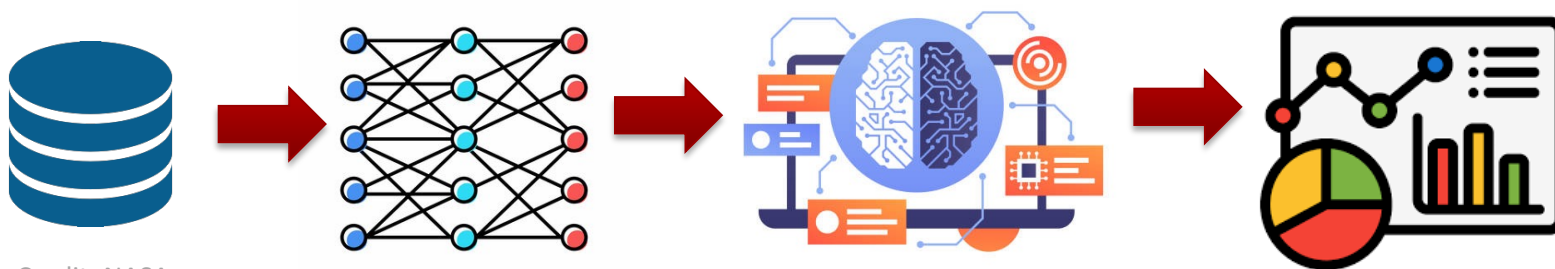
- Radar Tracks: 47 Facilities
- ~35 GB/month (compressed).
- ~268 GB/month (uncompressed)
- Weather and Forecast (Entire NAS): CIWS ~233 GB/month

➤ Veracity

- Data dropouts
- Duplicate tracks
- Track ending in mid air
- Reused flight identifiers

➤ Variety

- Numerical (continuous/binary)
- Weather (forecast/actual)
- Radar/Airport meta data
- ATC Voice
- ASRS text reports (Pilot/Controller)



Credit: NASA

Aviation Safety Information Analysis and Sharing (ASIAS)

ASIAS 1.0

ASIAS 2.0

ASIAS 3.0

Characteristics of the Program:

- Data silos
- Distributed architecture
- Manual data-fusion process
- Sharing of aggregated, de-identified results via web portal
- Baseline governance, roles, and responsibilities
- Commercial and general aviation communities

Key Changes:

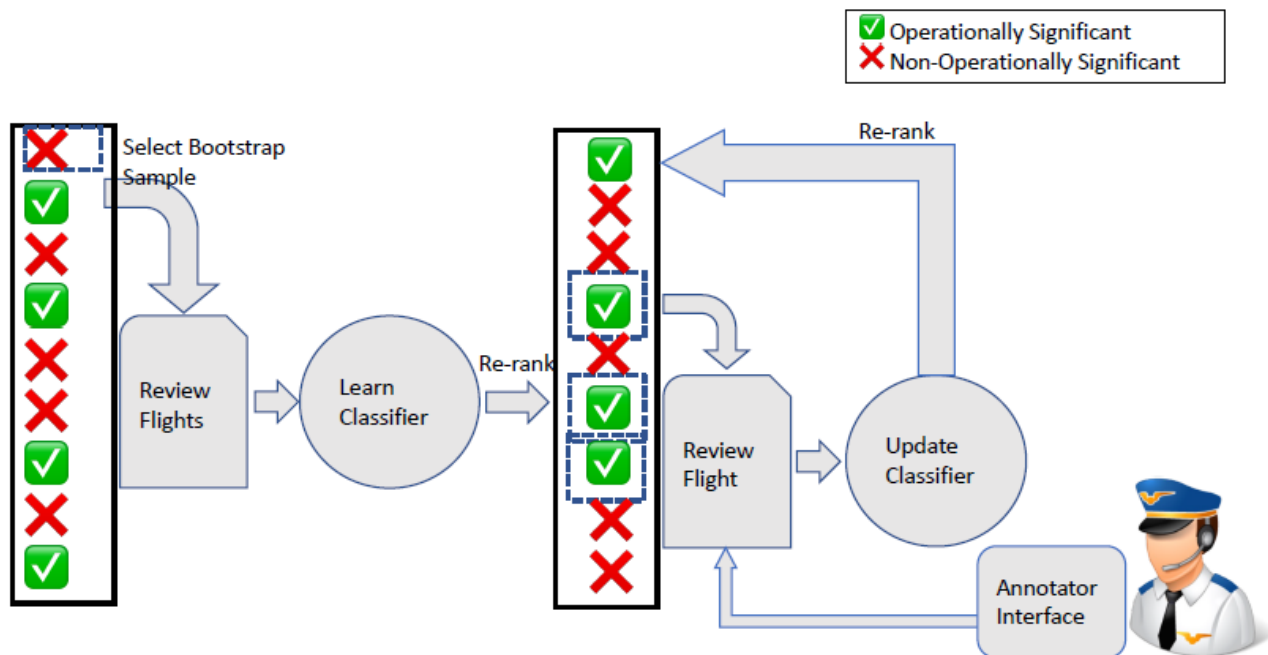
- Integrated production system to support analytic processing requirements
- Higher volumes of data and processing speeds
- Automated capabilities to fuse disparate data sources
- Expanded fusion governance model

Key Changes:

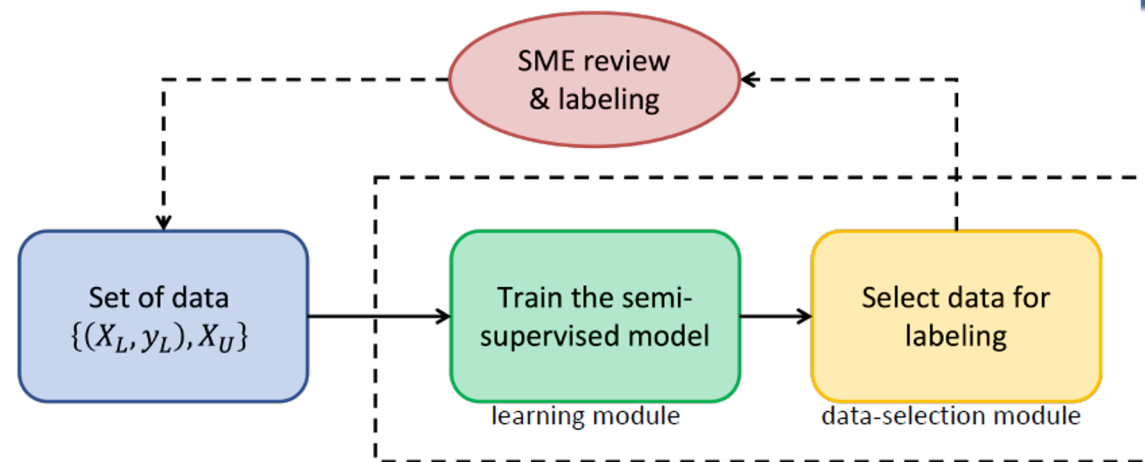
- Predictive analytics and advanced tools to identify emerging risks
- Expansion – new communities, additional data, improved operating processes
- Transformed collaboration – more agile, innovative interactions
- Enhanced access to data by partners, to conduct specific analysis in controlled environments
- Application of fused data to improve quality of analysis



NASA-Developed Data Science Methods

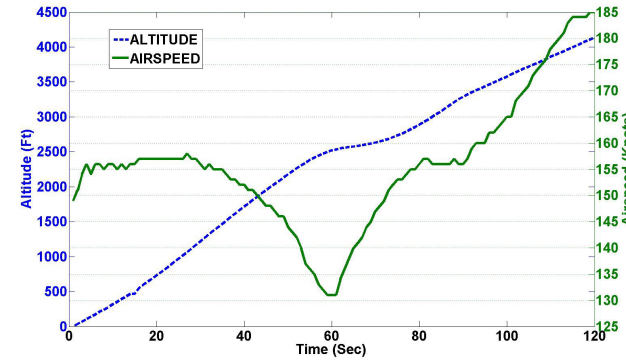
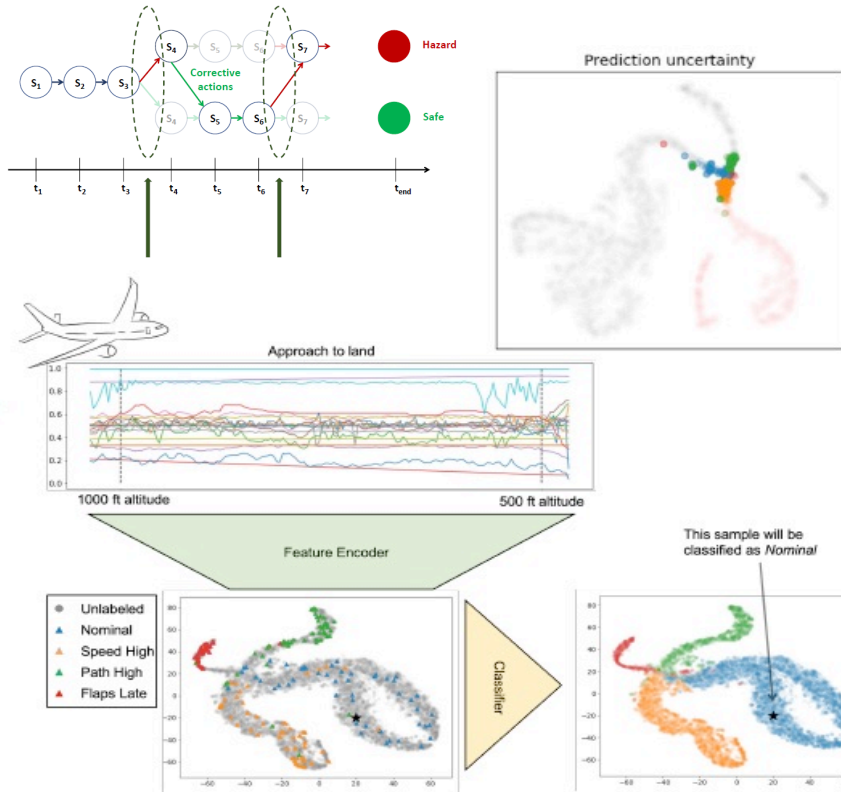


Multiple Kernel Anomaly Detection (MKAD)
with Active Learning (Human Feedback)

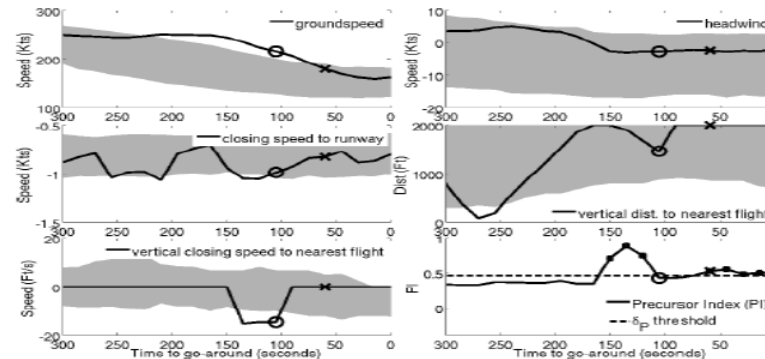


Semi-Supervised Active Learning for
Anomaly Detection (SALAD)

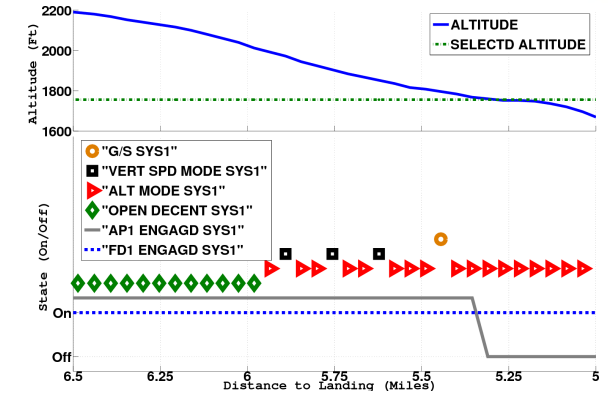
NASA-Developed Data Science Methods



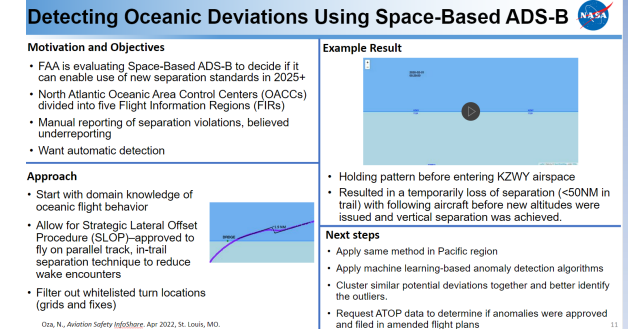
Drop in Airspeed



Energy Mismanagement
– Precursor to Go-Around



Mode Confusion



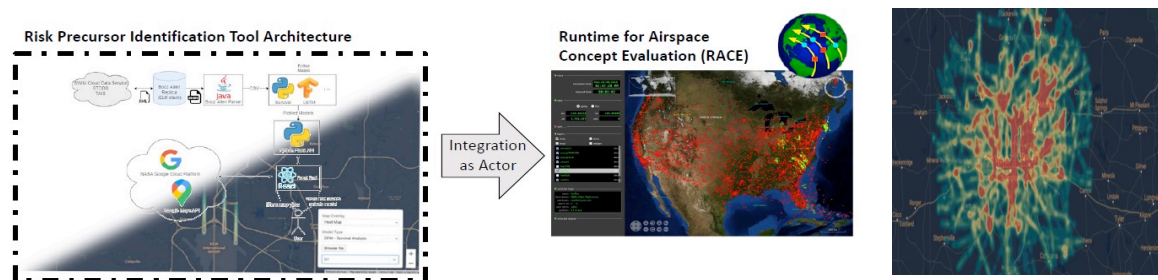
Oceanic Deviations

NASA-Developed Data Science Methods



Evaluated three machine learning models to identify flights that are at risk of unstable vertical approach with initial, narrow SWIM data sets

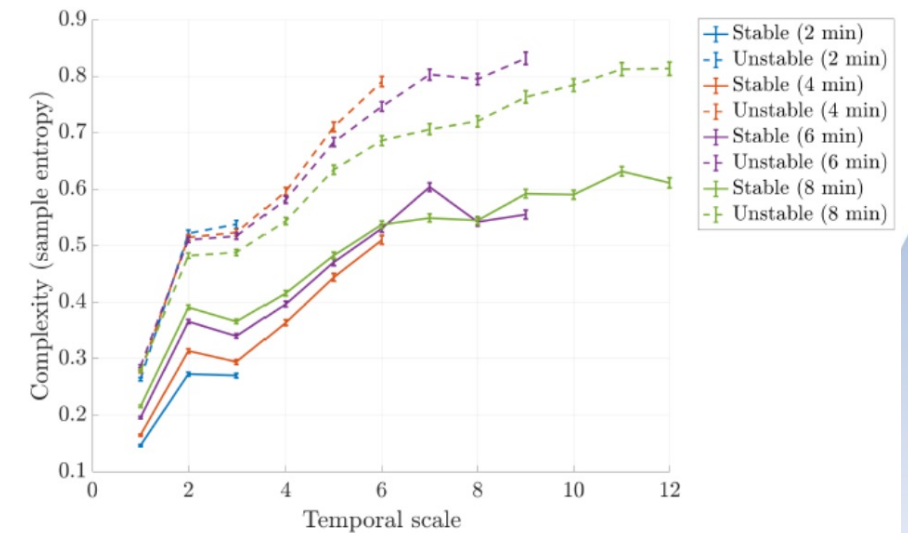
- Recommended Long Short-Term Memory (LSTM) neural network autoencoder that learns time dependence and encodes and decodes temporal relationships.
- Determines if the flight should be flagged for review and had an accuracy 36% better than a naïve predictor
- Laid foundation for Risk Precursor Identification Tools future integration with NASA's RACE



Booze-Allen Hamilton

Examined entropy dynamics between stable and unstable approaches at different time instances prior to landing

- Significantly different complexity distributions are evident minutes before a plane crosses the 1,000 ft threshold (i.e., before an approach is deemed stable or unstable)

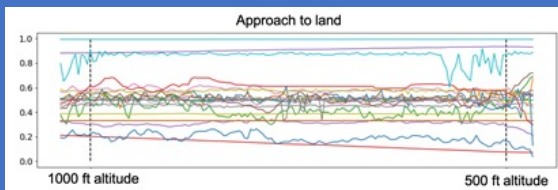


University of Florida

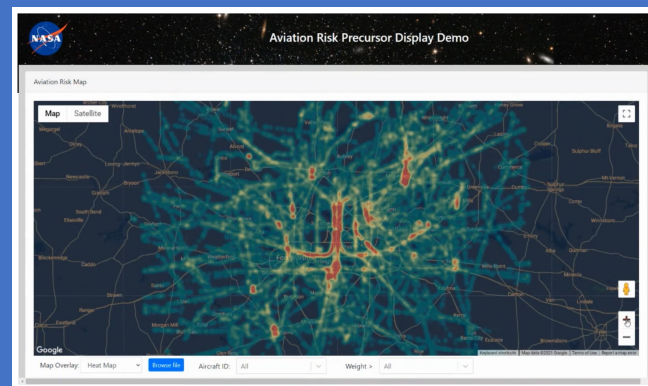
NASA Technical Challenge-1 Research

TC-1 improves air carrier safety management systems using ML and previously-unused data sources to allow airlines to predict and mitigate safety threats in time to prevent them. Airlines also gain new insights on safety they didn't have before.

ML Enabled Data Analytics: Semi-supervised ML algorithm for detection of safety events at a major airline partner using FOQA data to detect unstable approaches, crossing deviations, and previously-unknown safety issues with more efficiency than traditional analytics methods.



HC2S SOTERIA STUDY: Partners can identify productive safety behaviors in addition to effective threat and error management behaviors. This approach enables training and procedures to be more effective and help train crews to be more resilient.

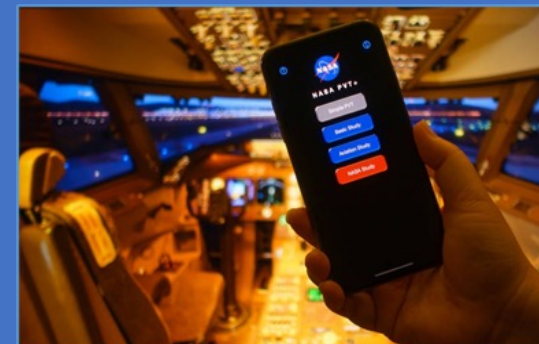


Aviation Risk Precursor Identification (ARPI) technology prototype:

Implementation of machine learning methods to anticipate and resolve potential safety issues, predict the health and robustness of aviation systems, and analyze integrated risk in terminal area operations and ground operations.

Non-Traditional Safety Data Monitoring and Analysis:

Deployment of NASA PVT+ app supports research on strategies to mitigate fatigue and increase pilot alertness and performance. Airline carrier partners benefit through improvements to their SMS Fatigue Risk Management programs.



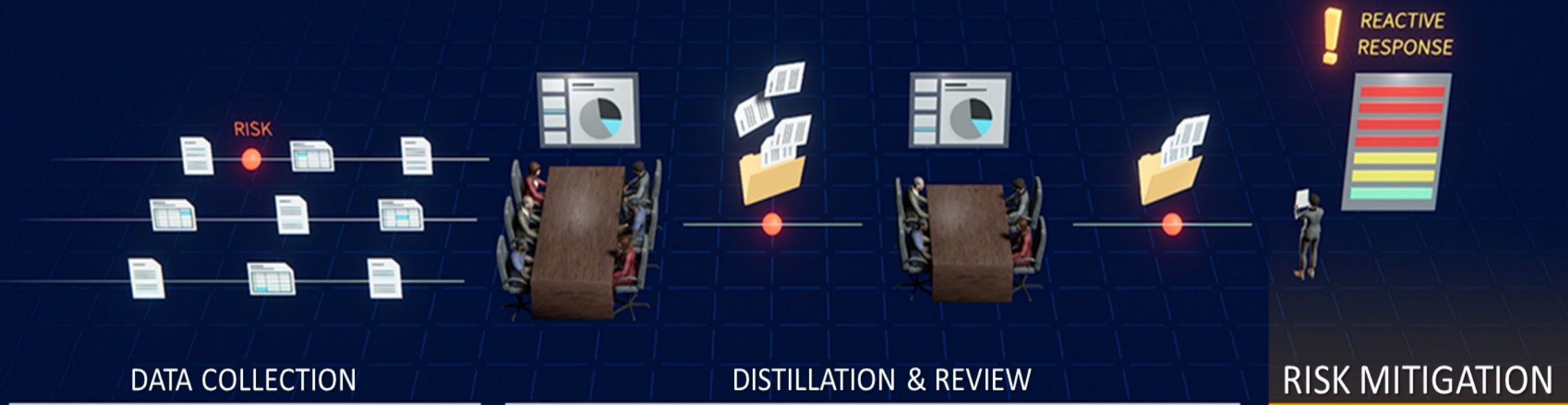
TC-1 directly aligns with ARMD's Strategic Thrust 5 to provide In-Time System-Wide Safety Assurance. In addition, the impact supports strategic industry partnerships, a key ARMD priority. Our partners include:



Current SMS for Air Carrier Operations



SMS



Credit: NASA

ML/AI Enabling In-Time Safety



IASMS

DATA COLLECTION &
AGGREGATION

FUSION OF BIG
DATA SETS

RISK MITIGATION

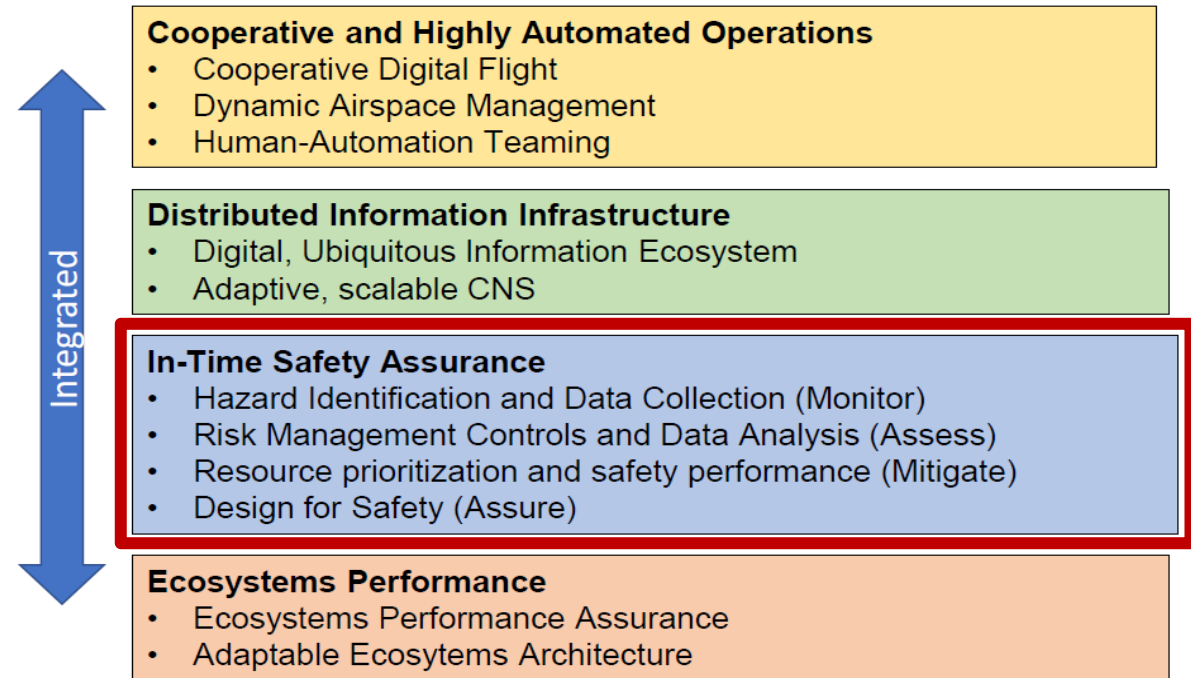
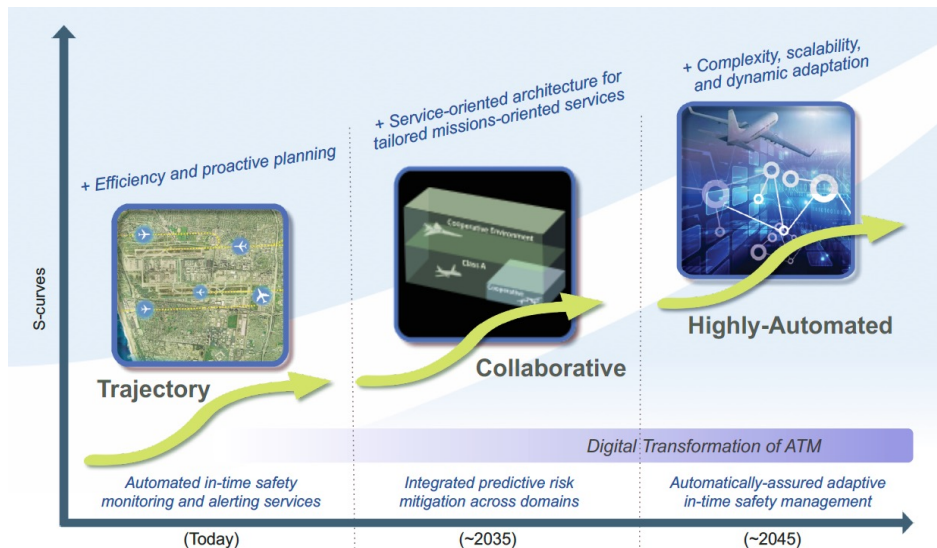


Credit: NASA

In-Time Integrated System-Wide Safety Assurance



“A broad range of safety systems that proactively mitigate risks and demonstrate innovative solutions while ultimately ensuring safety to the community on the ground and in the airspace, employing services, functions, and capabilities that perform comprehensive monitoring and communication of the aviation system state, assessment of elevated risks, and mitigation actions to assure safety.”



Attributes

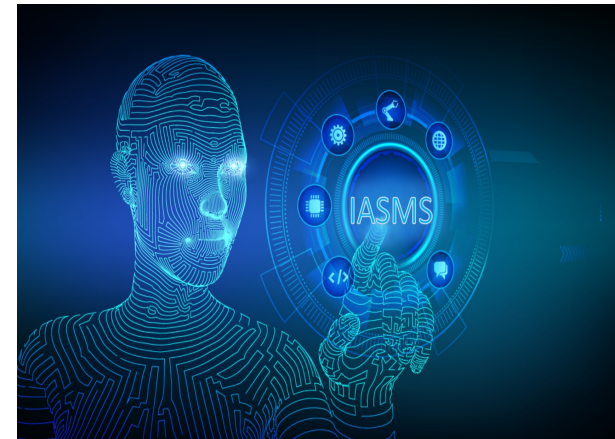


- Increasingly scalable
- Decreasingly labor-intensive
- Dramatically increased responsiveness and timeliness
- Integrated risk management and safety assurance
- Automatically assured and adaptive in-time safety threat management

Addressing Research Needs

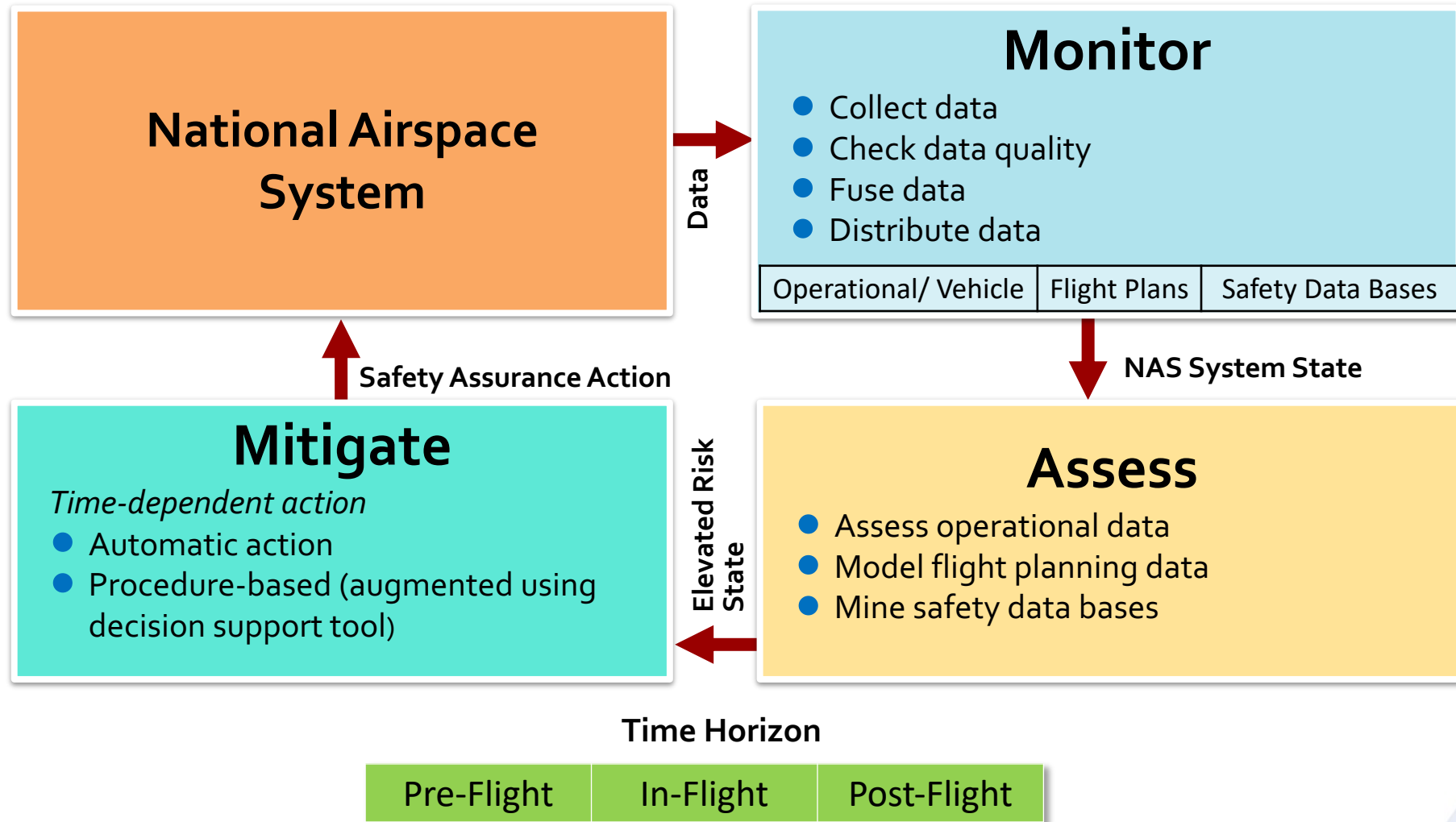


- Expanded TC Goals for Commercial Air Operations IASMS
 - Technical Challenge 1 (TC-1) was intended to provide initial IASMS SFCs for near-term commercial operations focused narrowly on terminal area risks as case to begin build of IASMS foundations
 - TC-6 expands upon current IASMS efforts (including TC-2, TC-5) toward a proactive and predictive analysis to enable in-time safety risk management and safety assurance with purview focus more broadly for traditional commercial operations
 - TC-6 significantly extends safety analytical capabilities toward a fully functioning IASMS aligned with development of NAS-wide fully integrated in-time predictive detection and assessment by 2045 through:
 - In-time active, proactive, predictive, and prescriptive data analytics
 - “Learning from All Operations”
 - System-Wide Safety Intelligence
 - IASMS system design modeling and human-system integration
 - Prototypes and demonstrations

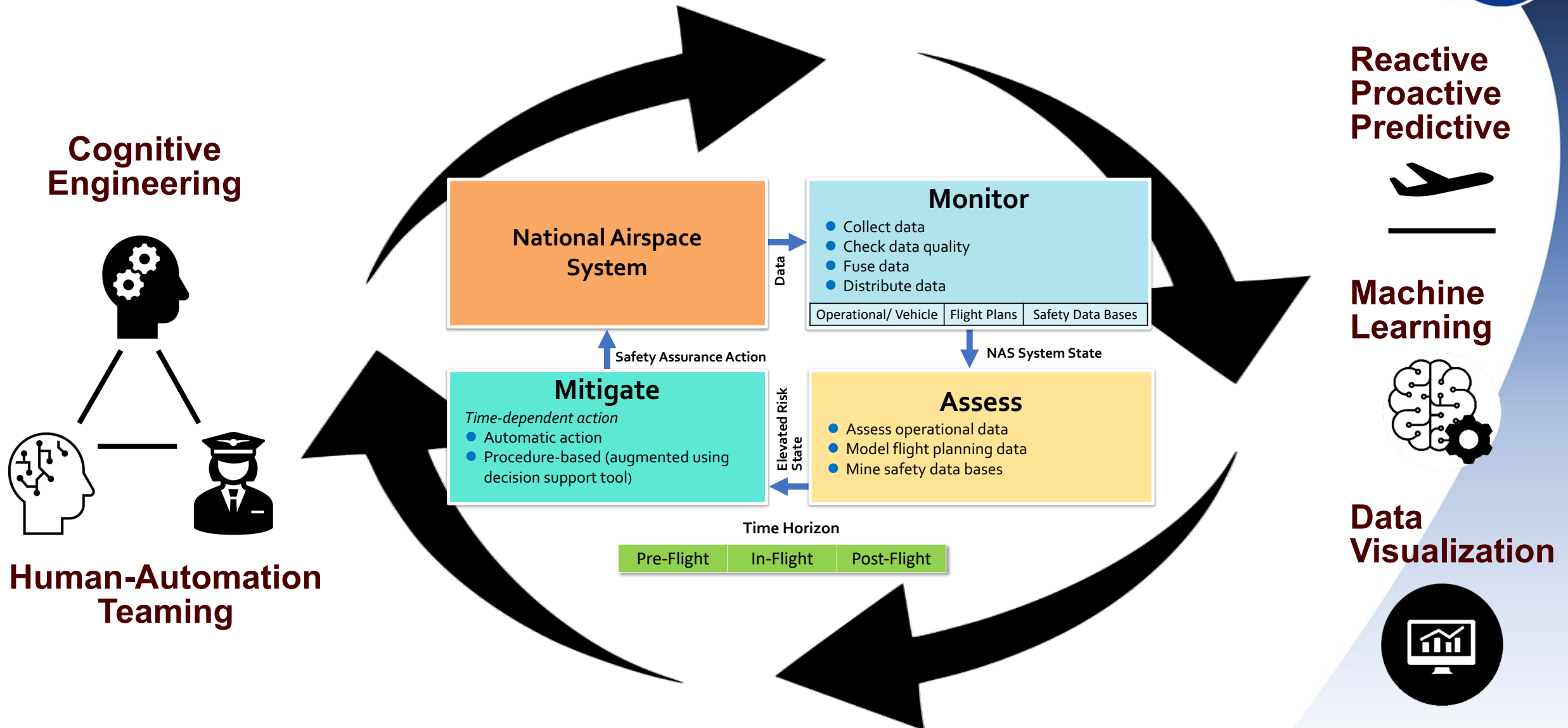


Credit: NASA

IASMS Safety Functions for Risk Management and Safety Assurance



In-Time System-Wide Safety Assurance



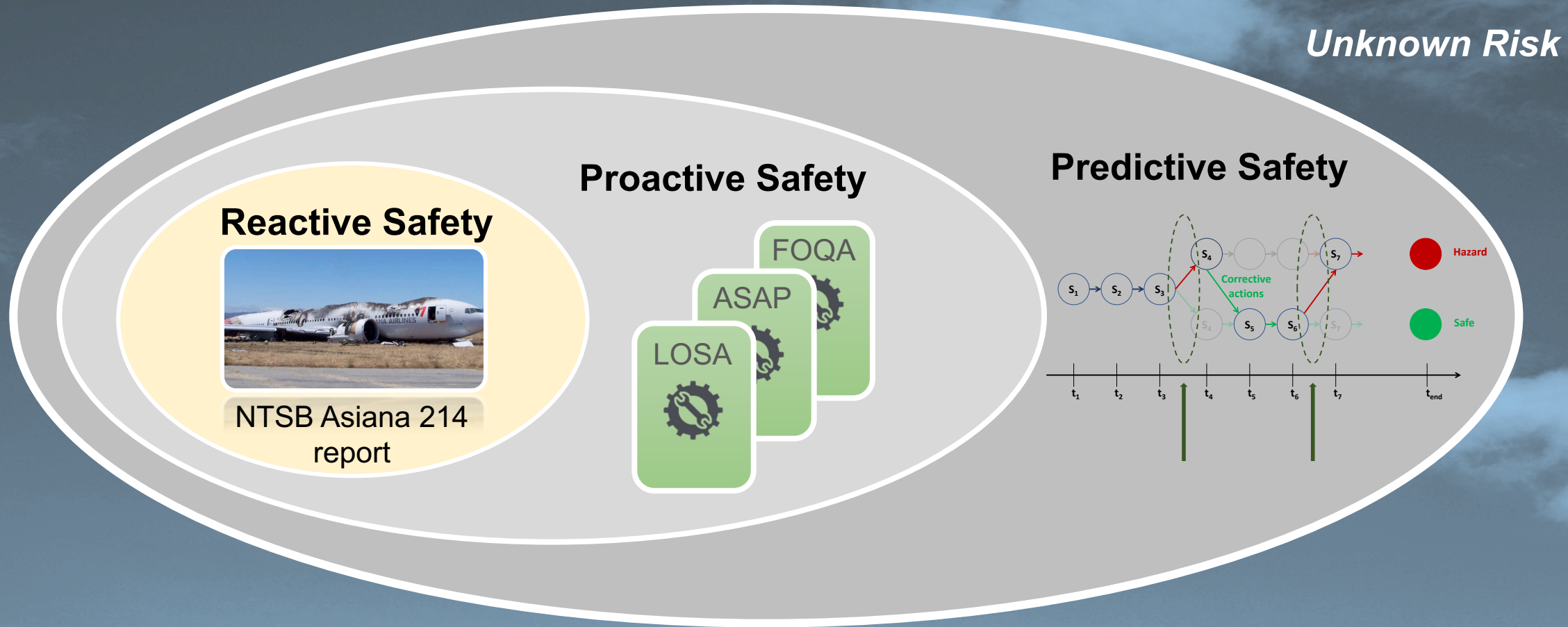


Discussion



- Research and technology challenges presented must be addressed to permit a key enabler of IASMS: Safety Intelligence
- Data Analysts' roles and responsibilities
 - Natural Language Processing (NLP) use in airline industry include:
 - Voluntary safety reports can also be analyzed using NLP (Paradis et al., 2021)
 - NLP to aircraft maintenance to improve safety and efficiency involving coding voice transcriptions of mechanics' findings and actions (Carvalho, 2022)
- Current and Future Safety Intelligence

Progression of Safety Intelligence



Less Data

Limited Number
of Accidents

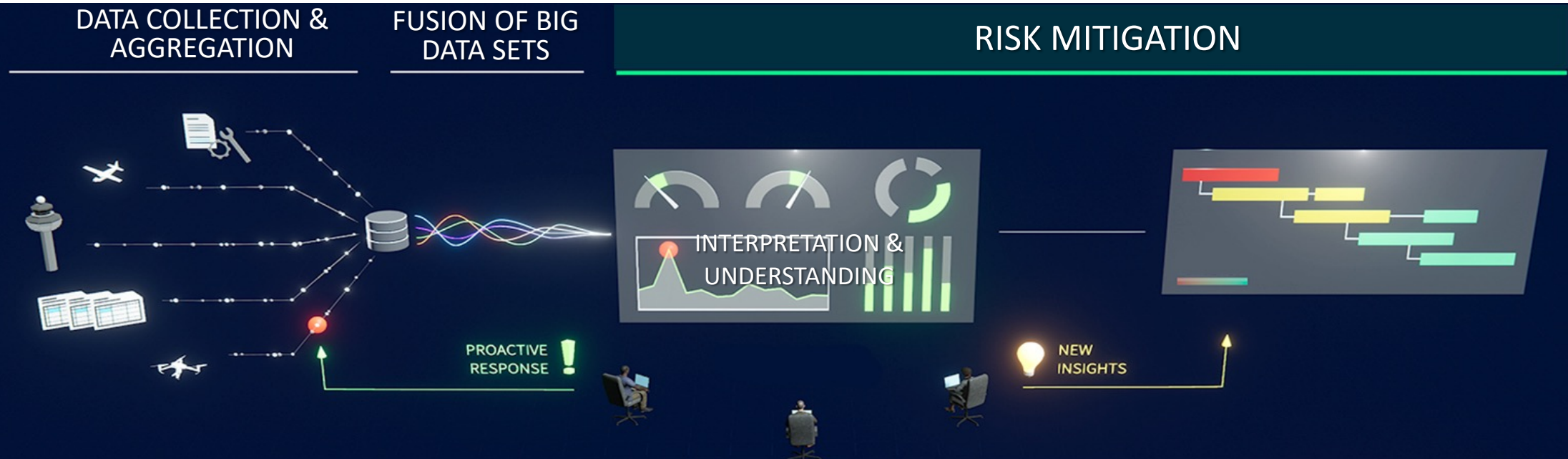
Current Numbers
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Large Number
of Future Flights

More Data

Modernization of Airline SMS Using IASMS

IASMS



Monitor

Assess

Mitigate

SMS





System Wide Safety

National Aeronautics and
Space Administration



Thank you for your attention!

Questions?