Methods to Improve Safety Risk Management and Safety Assurance:

In-Time Aviation Safety Management Systems

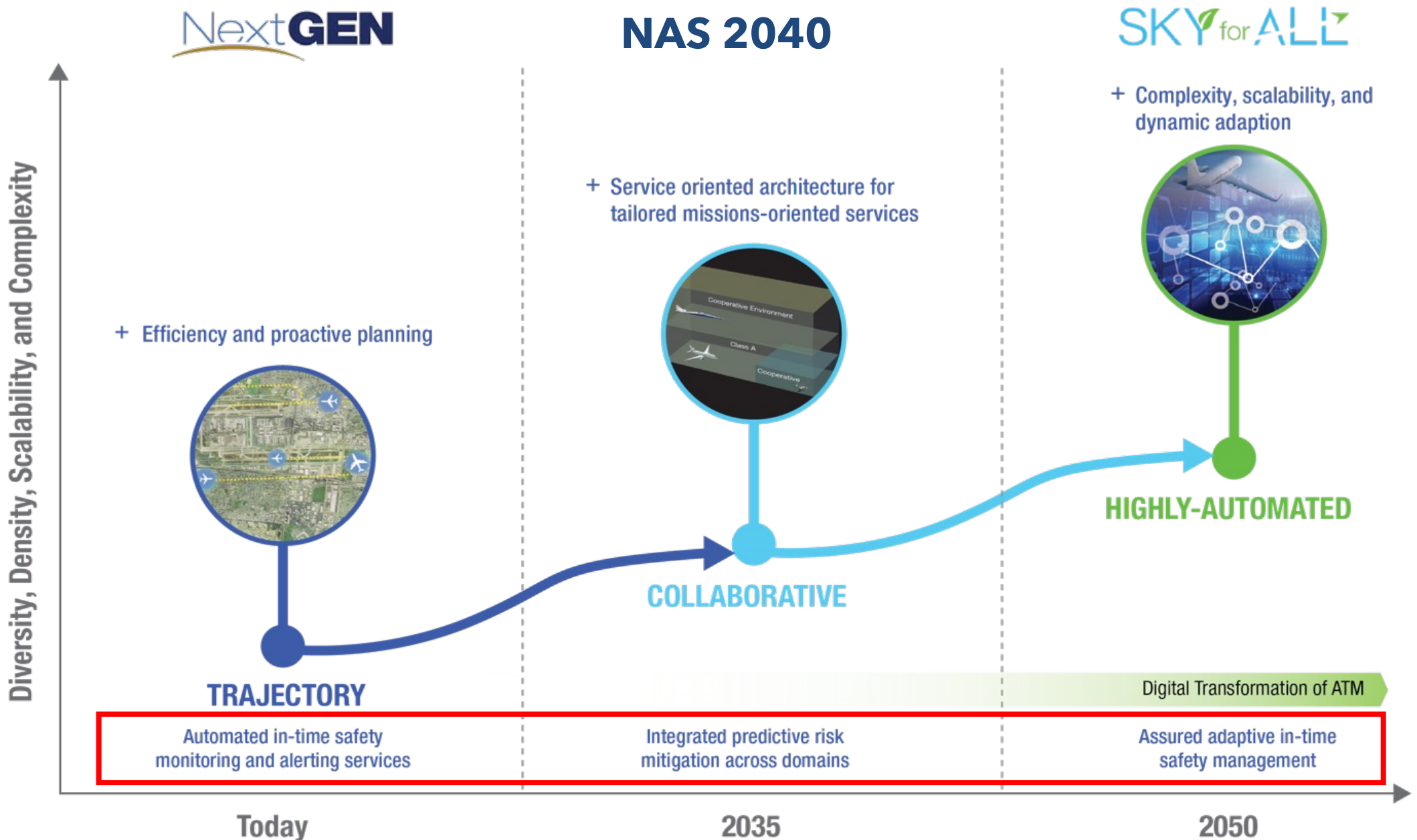
Dr. Kyle Ellis – *Project Manager, NASA System-Wide Safety*

June 11th, 2024

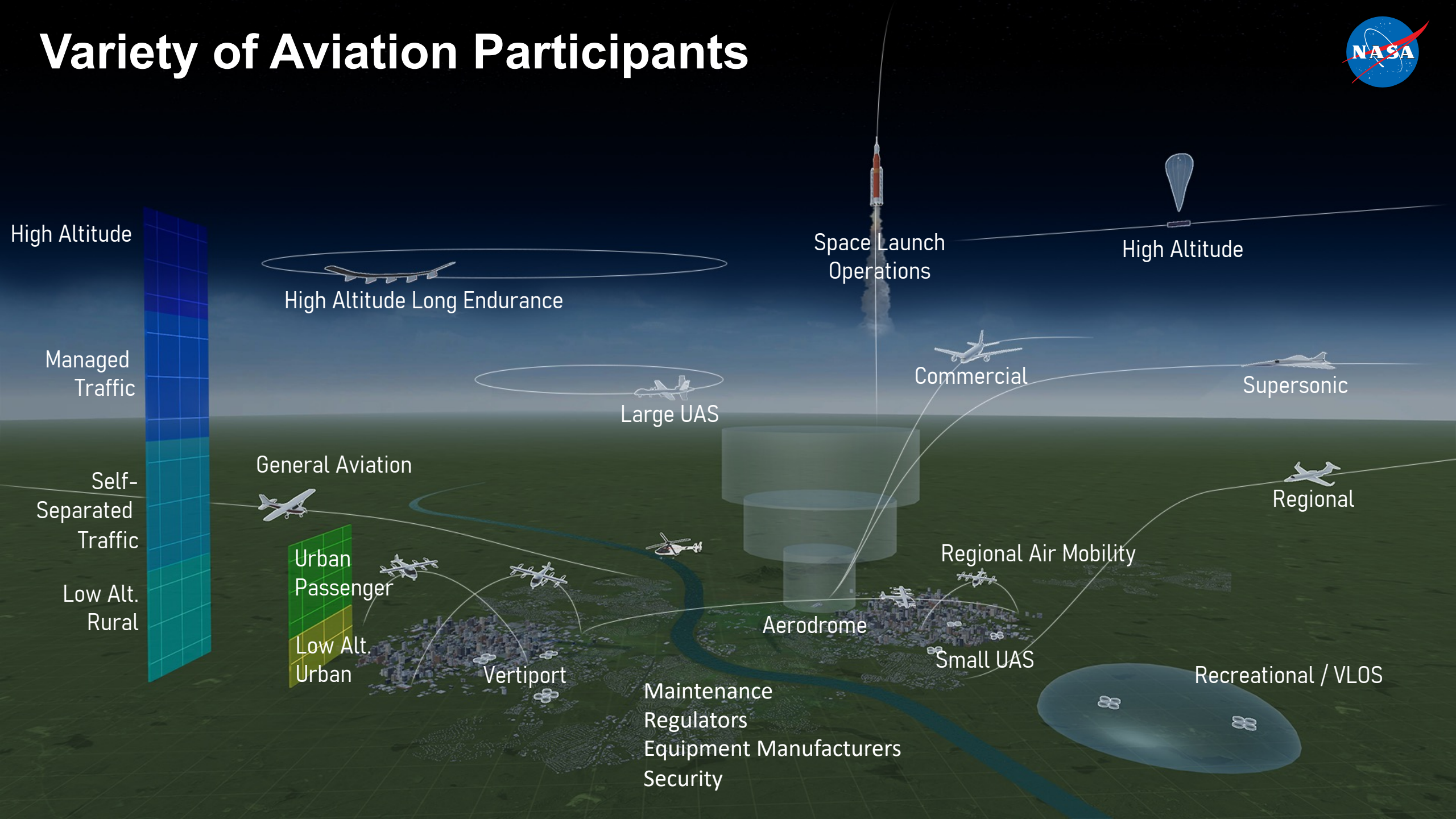
Aeronautics and Space Engineering Board

NATIONAL ACADEMIES *Sciences Engineering Medicine*

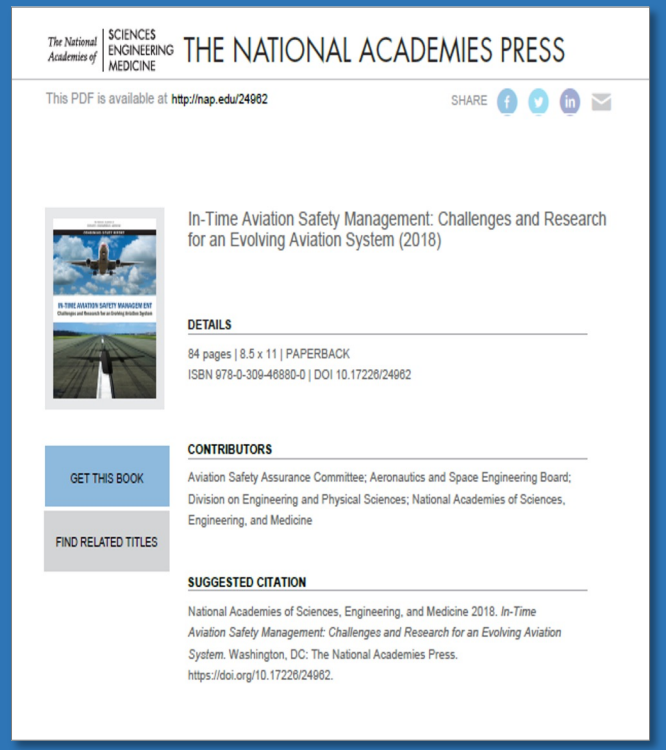
Future Airspace and Safety



Variety of Aviation Participants



Advancements in Safety Risk Management and Safety Assurance



The National Academies of SCIENCES ENGINEERING MEDICINE THE NATIONAL ACADEMIES PRESS

This PDF is available at http://nap.edu/24962 SHARE

In-Time Aviation Safety Management: Challenges and Research for an Evolving Aviation System (2018)

DETAILS

84 pages | 8.5 x 11 | PAPERBACK
ISBN 978-0-309-46880-0 | DOI 10.17226/24962

GET THIS BOOK

FIND RELATED TITLES

CONTRIBUTORS

Aviation Safety Assurance Committee; Aeronautics and Space Engineering Board; Division on Engineering and Physical Sciences; National Academies of Sciences, Engineering, and Medicine

SUGGESTED CITATION

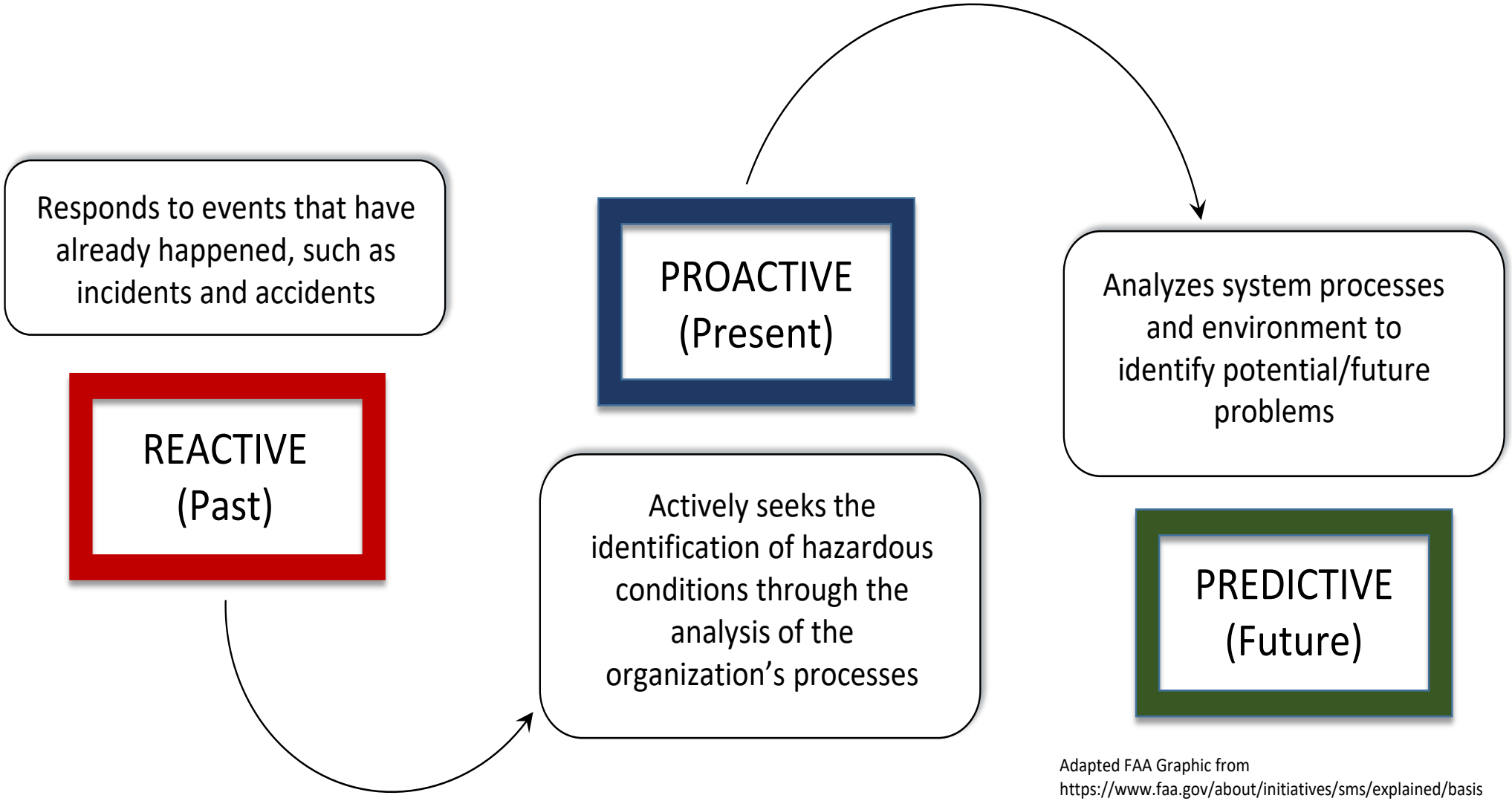
National Academies of Sciences, Engineering, and Medicine 2018. *In-Time Aviation Safety Management: Challenges and Research for an Evolving Aviation System*. Washington, DC: The National Academies Press. https://doi.org/10.17226/24962.

Need: Wide variation of operator size and complexity of operations necessitates the development of tools and processes to quickly mitigate risks and hazards effectively and economically.

Objective: Improve Safety Intelligence. Develop ability 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 SMS processes supporting risk management and safety assurance.

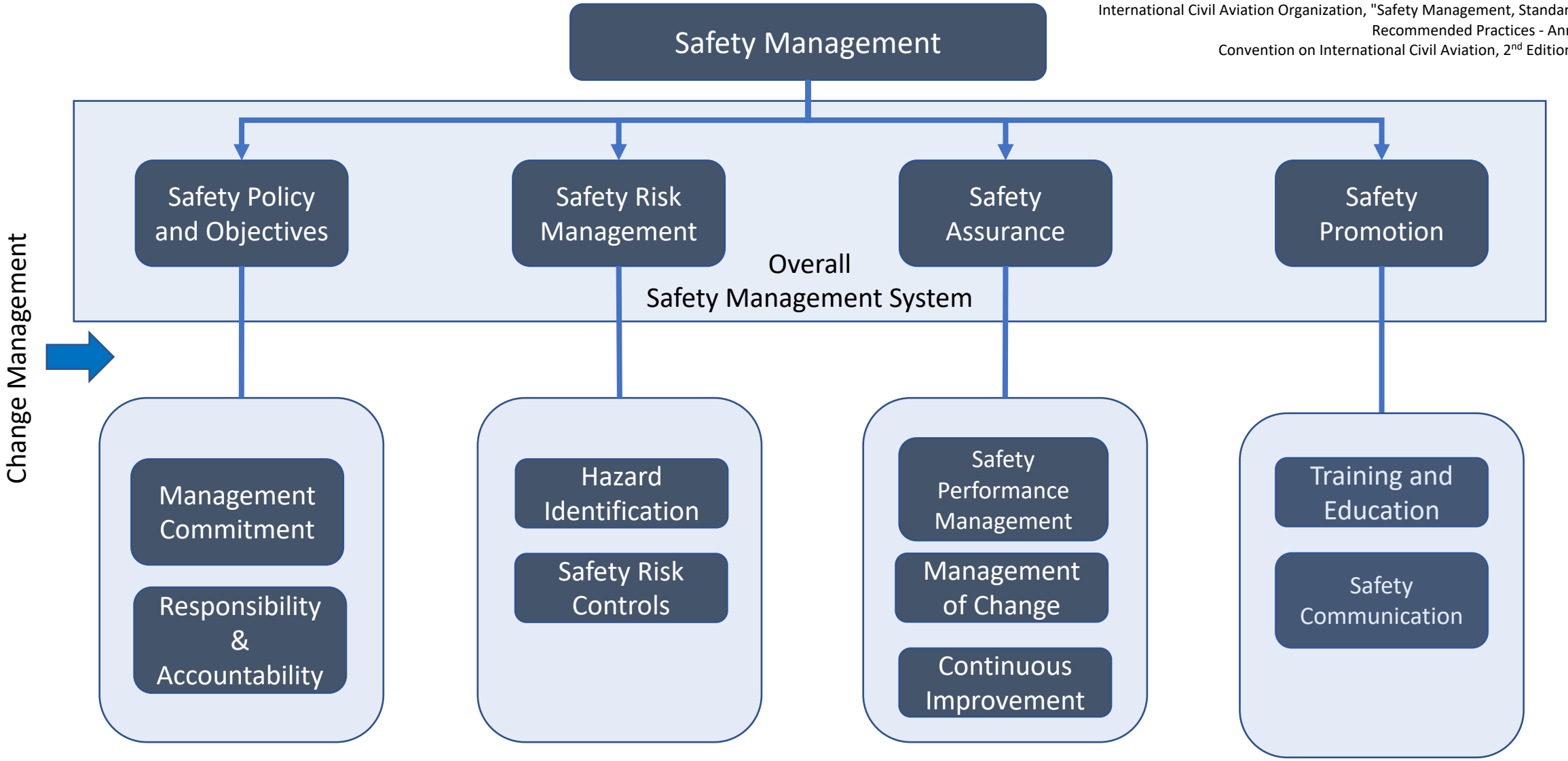
Progression of Safety Intelligence



Adapted FAA Graphic from
https://www.faa.gov/about/initiatives/sms/explained/basis

How We Achieve Aviation Safety Today

International Civil Aviation Organization, "Safety Management, Standards and Recommended Practices - Annex 19, Convention on International Civil Aviation, 2nd Edition, 2016



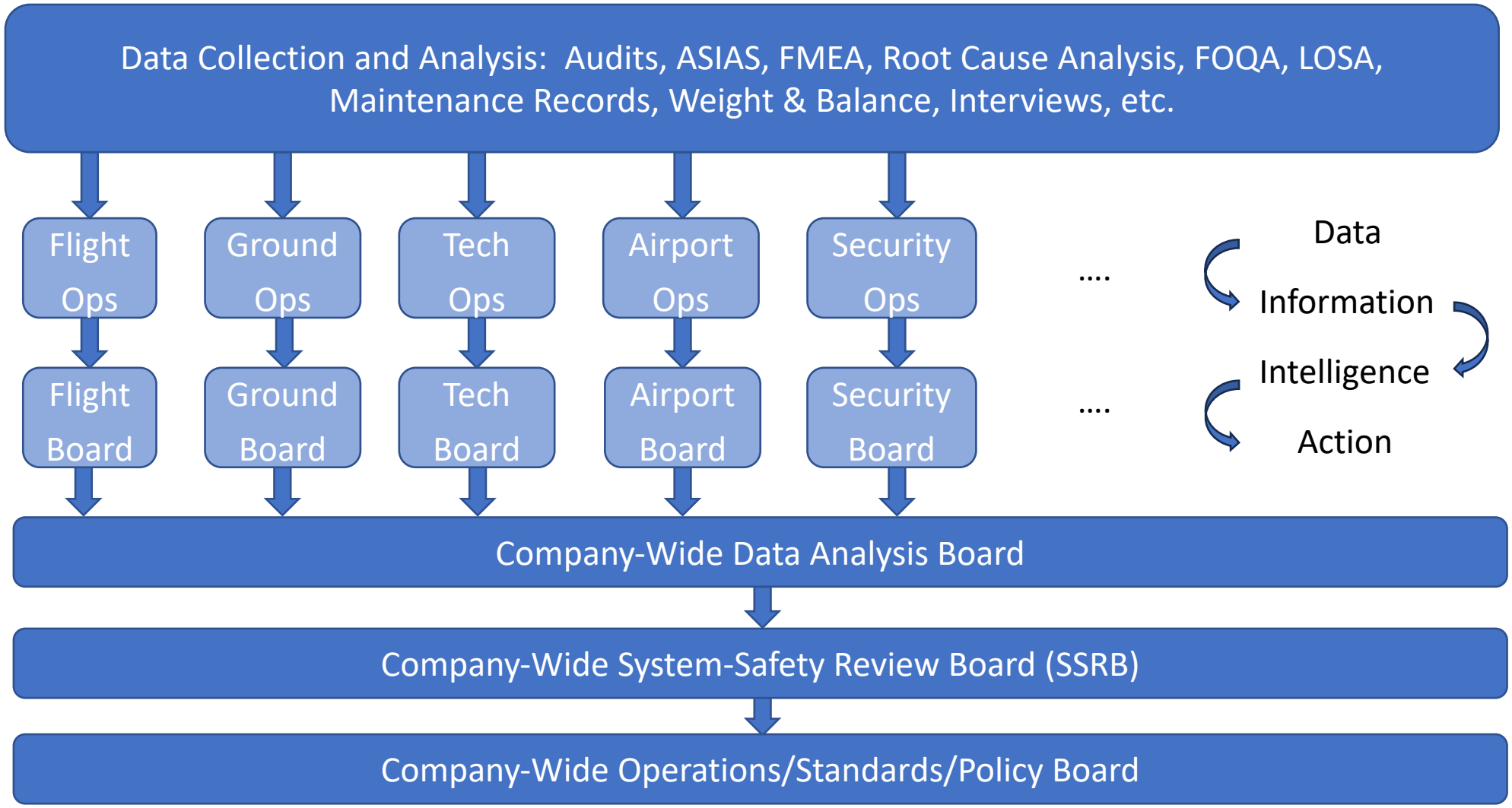
Current-Day Safety Management Systems

Current-day SMSs are primarily reactive—analysis based on data collected over month(s)

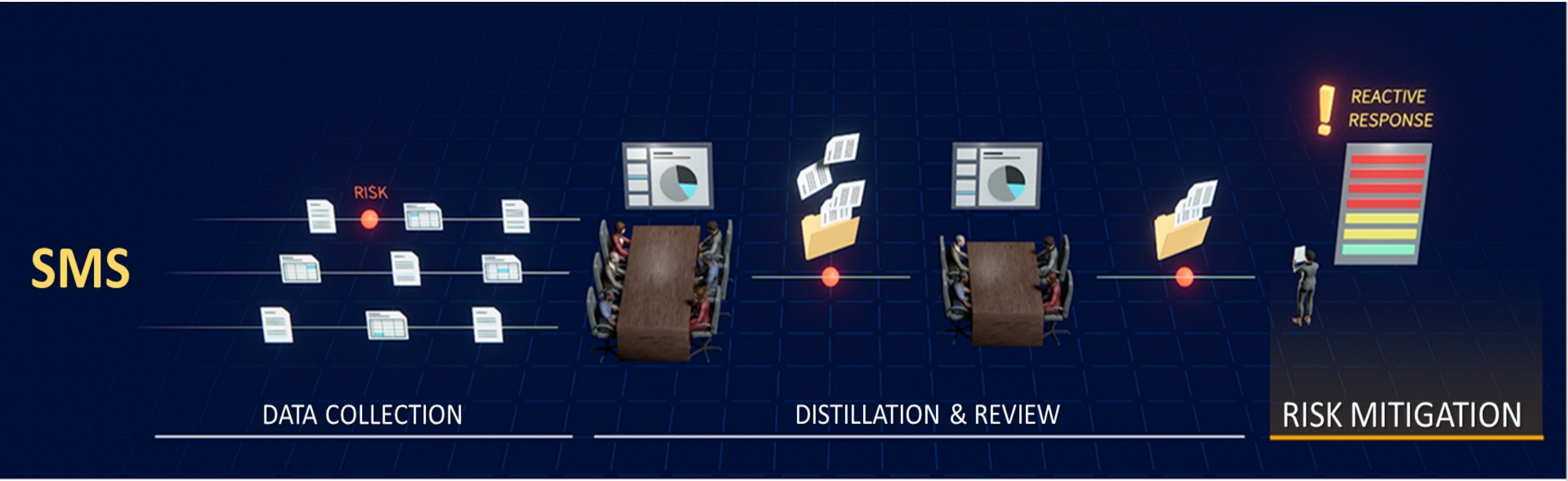
Data-Analysis Groups pull from data for their domain—each group ~8-10 hours/month

Data-Analysis Boards take recommendations from associated group—each board ~2-4 hours/month

Company-wide boards filter input from boards to eventual change or create operations, standards & policy—time spent varies widely



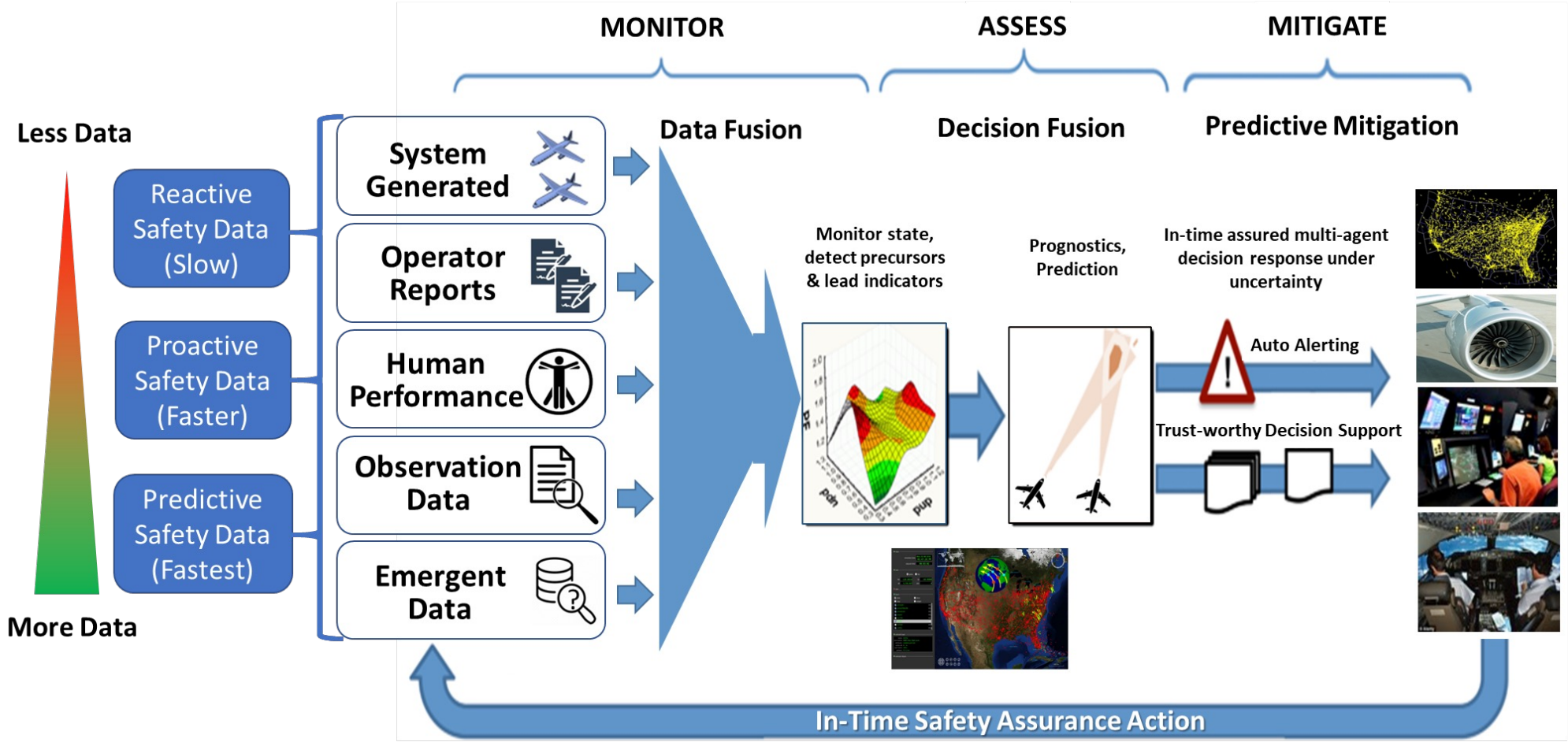
Current SMS for Air Carrier Operations



Credit: NASA

Increasingly In-Time Safety

Operational Needs	Improve in-time safety	Improve scalability	Improve accessibility	Increase participation
Future Aviation Goals	In-time Safety Assurance	Tailored Safety	Interoperability	



Credit: NASA

DATA COLLECTION & AGGREGATION

FUSION OF BIG DATA SETS

RISK MITIGATION

Monitor – Assess - Mitigate

CONTINUOUS DATA EXCHANGE

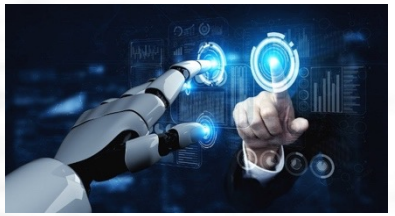
MACHINE LEARNING

AUTOMATED MONITORING

PROGNOSTIC RISK MODELING

ALERTING AND RESPONSE

Verification & Validation

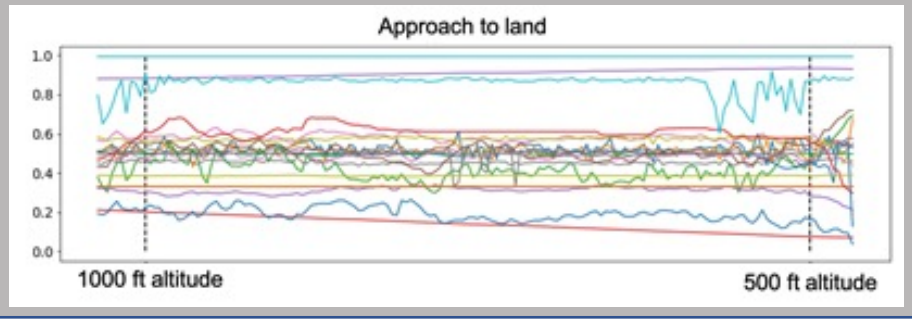


Assurance of Autonomy

NASA Research on Terminal Area Risk Analysis

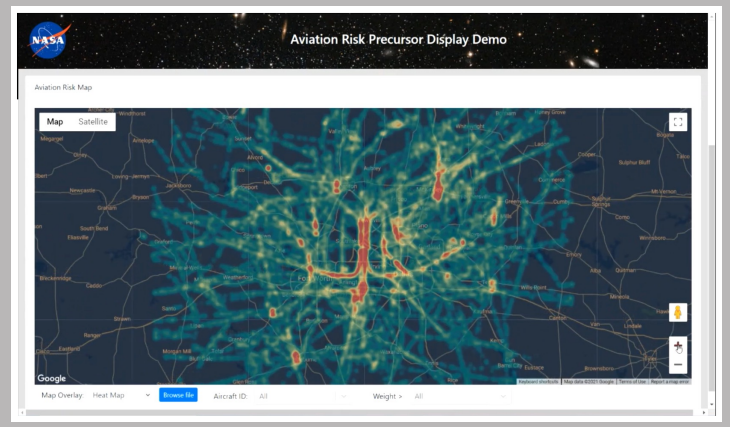
Improves air carrier safety management systems using ML and previously-unused data sources to allow airlines to predict and mitigate safety threats in time to prevent them. Airlines also gain new insights on safety they didn't have before.

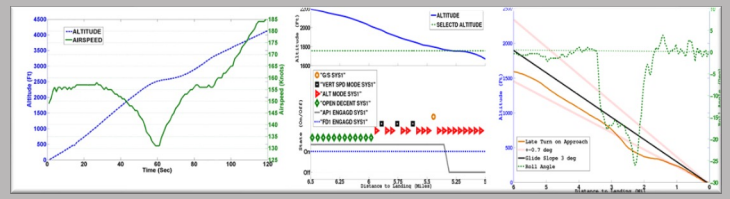
ML Enabled Data Analytics:



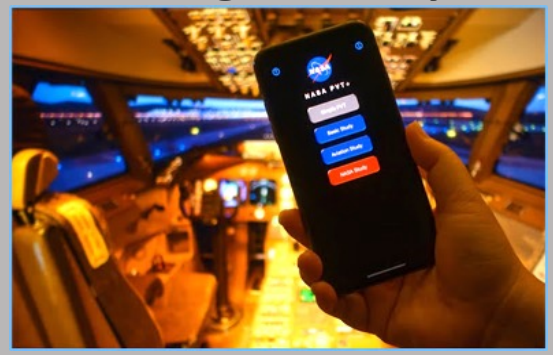
Safety-II SOTERIA Study:

Aviation Risk Precursor Identification (ARPI) technology prototype:





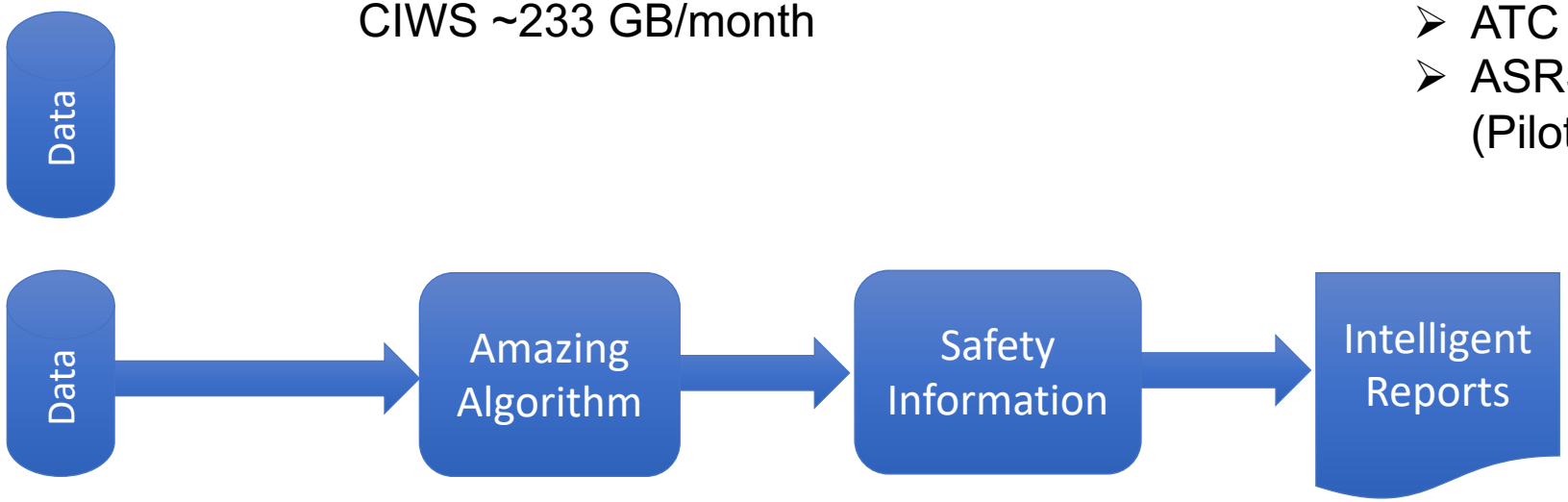
Non-Traditional Safety Data Monitoring and Analysis:



American Airlines · DELTA · Federal Aviation Administration · IATA · SWISS · BOEING · easyJet.com · FLIGHT SAFETY FOUNDATION · MITRE · UNITED

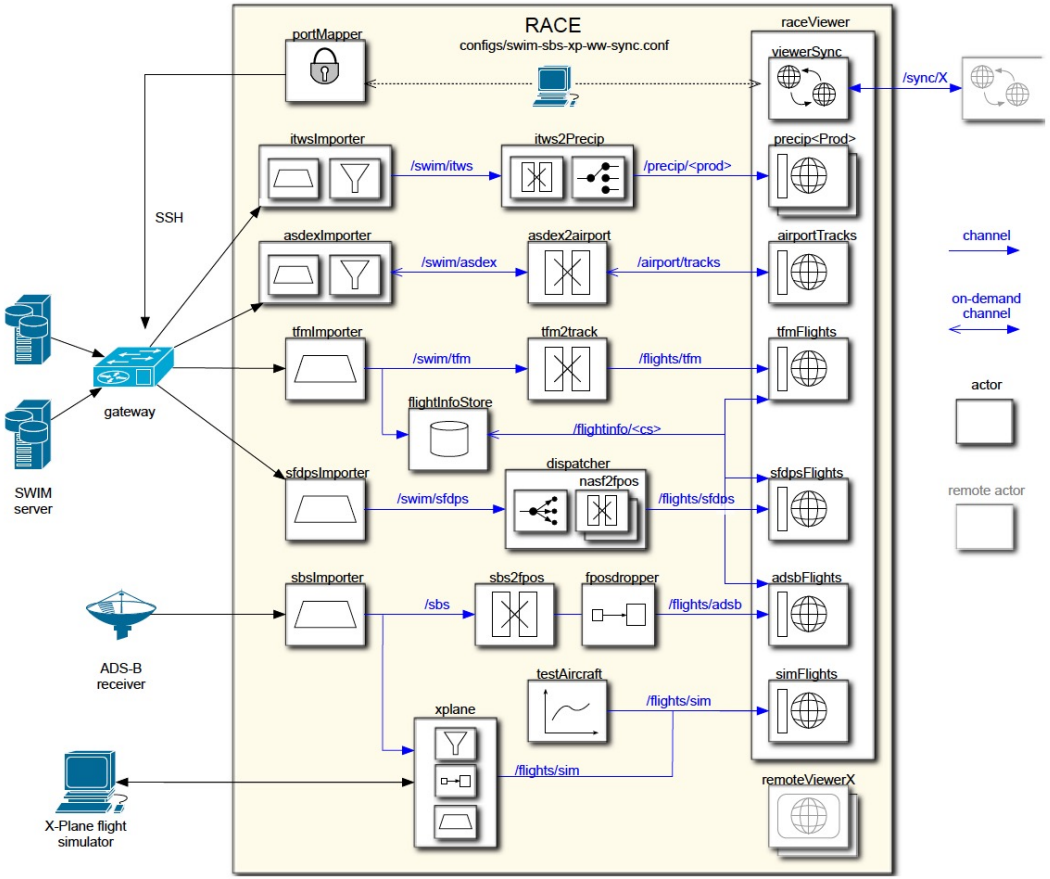
Data Challenges: The Four V's

- 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)

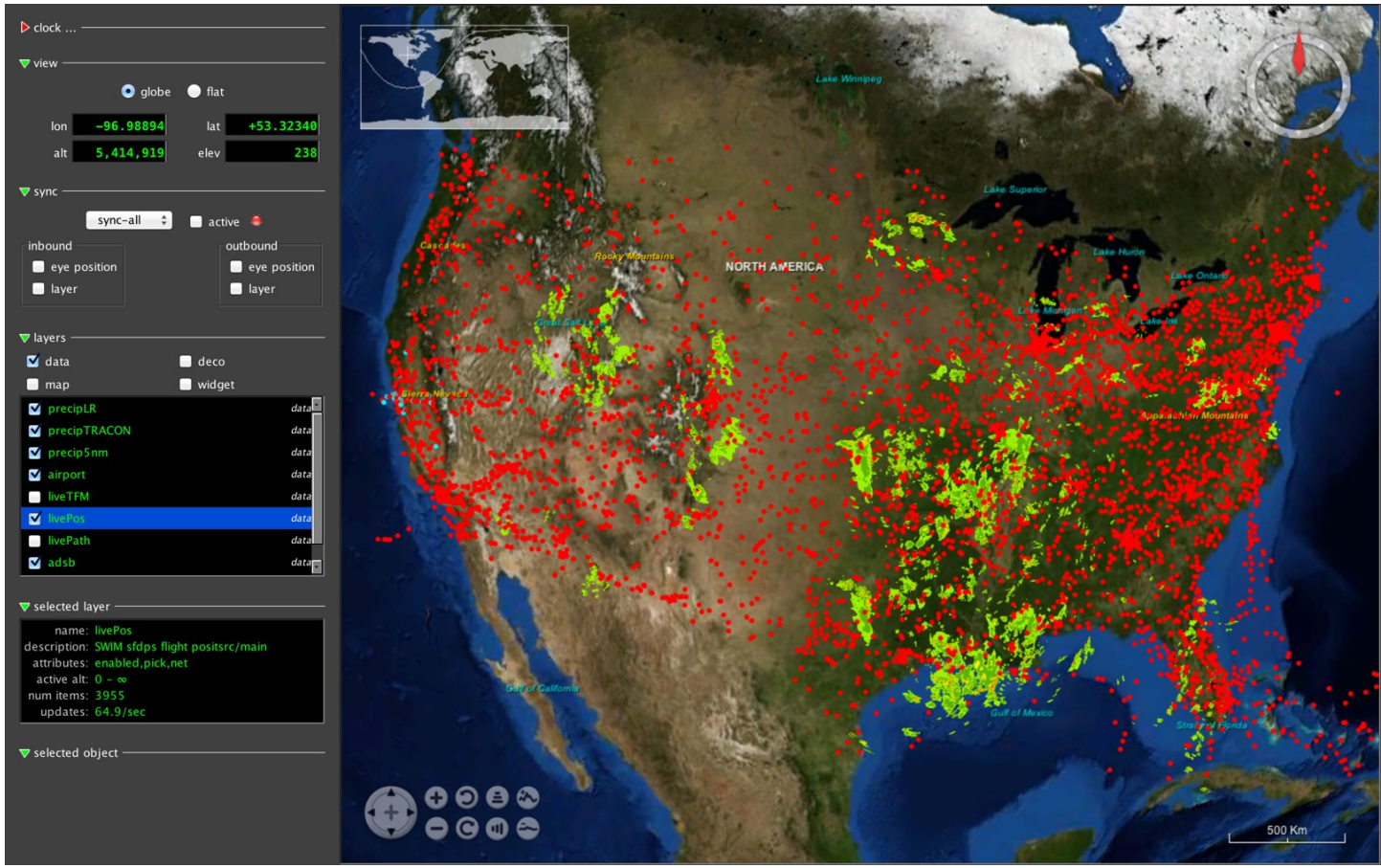


Systems Integration and Visualization

Imports Data (1000 msg/sec)

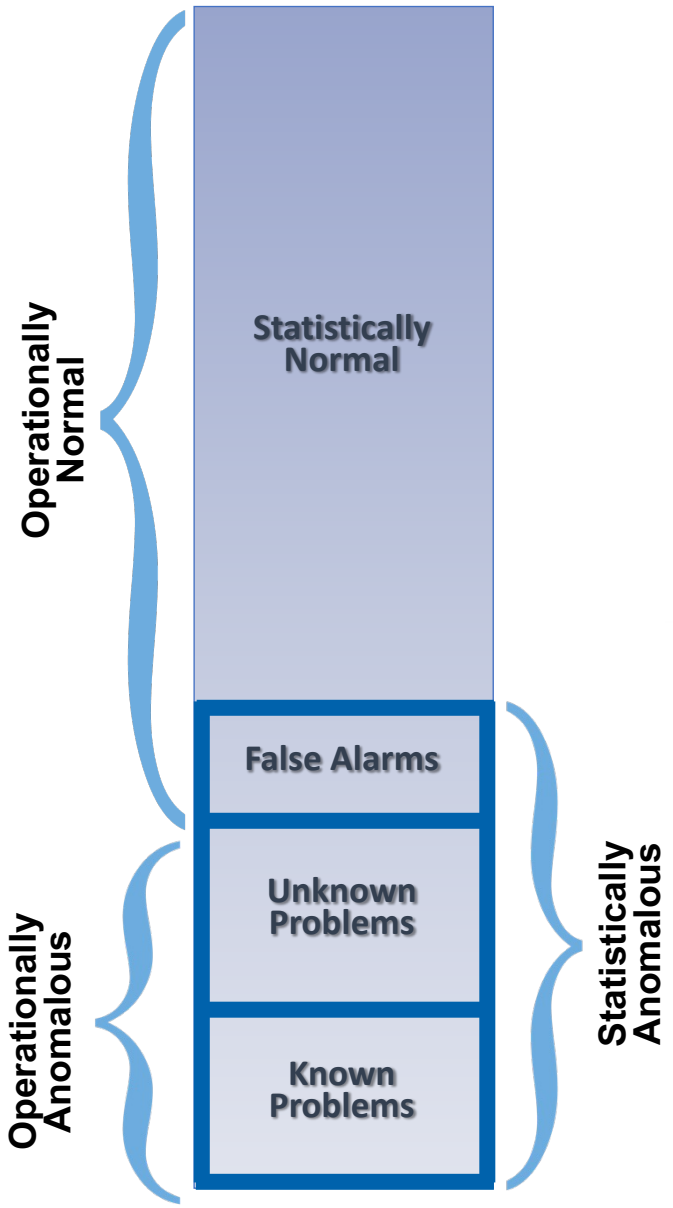


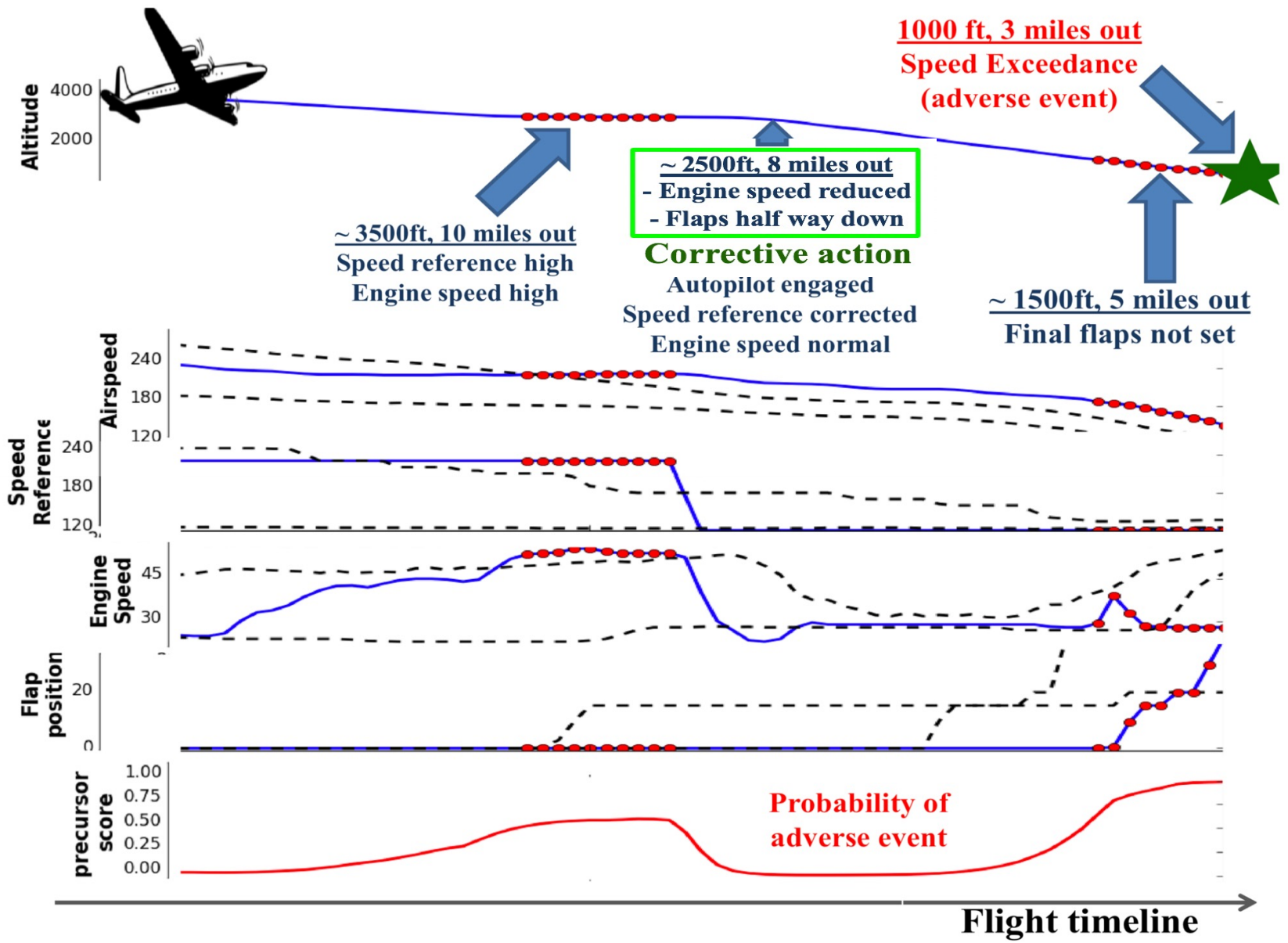
4,500 Simultaneous Flights



Credit: NASA

Discovery of Precursors in Time Series Data



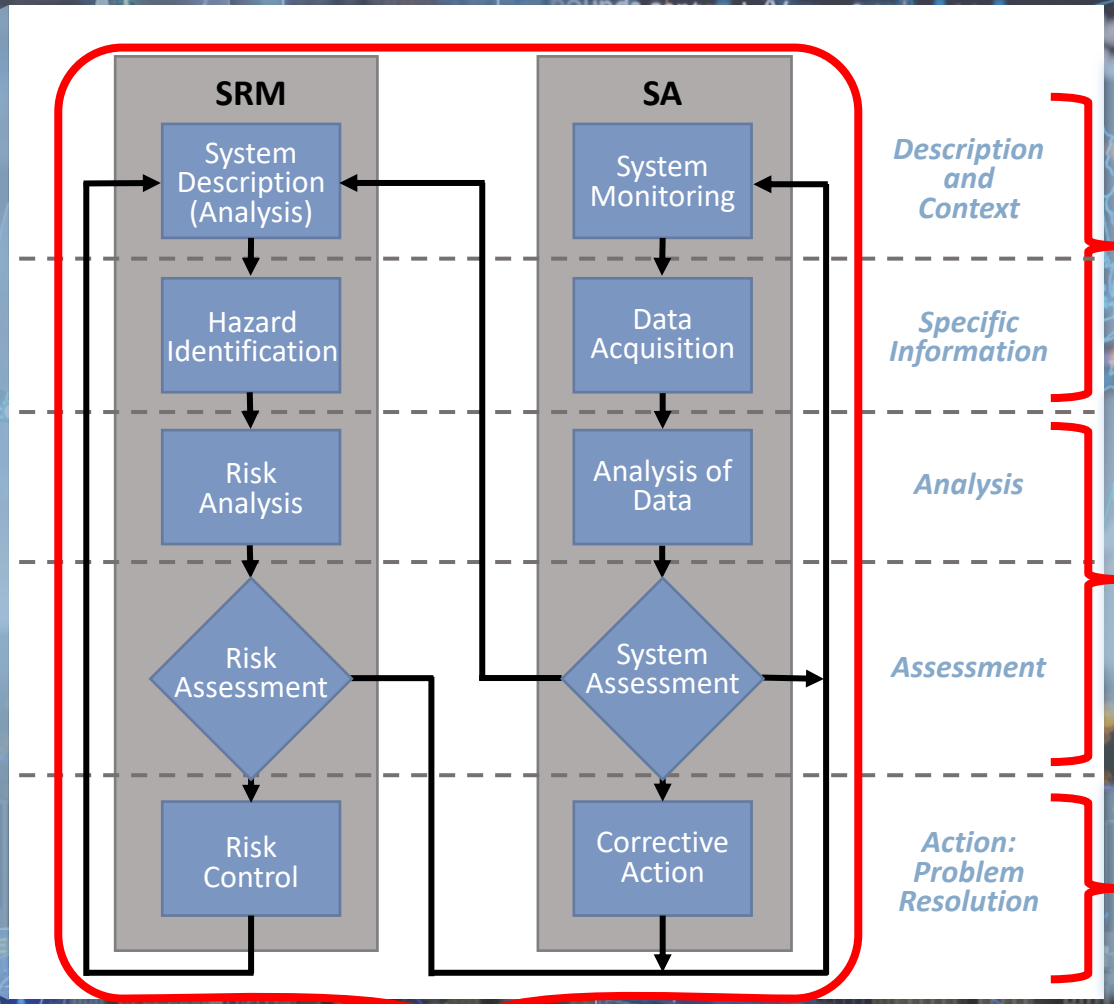


Safety Research Needs for NAS 2040

Needs*

- In-Time Safety Risk Mitigation
- Proactive -> Predictive Safety Management Systems
- Adopt ML/AI for predictive analysis and advanced data mining
- Build upon existing IT architectures for increased access to data and tools
- Improve system agility and responsiveness

*From ASIAS 3.0 ConOps



R&D Required:

- New Safety Databases
- Non-traditional data
- Data Fusion w/existing services
- Required vs. Voluntary Data
- Synthetic Data Generation

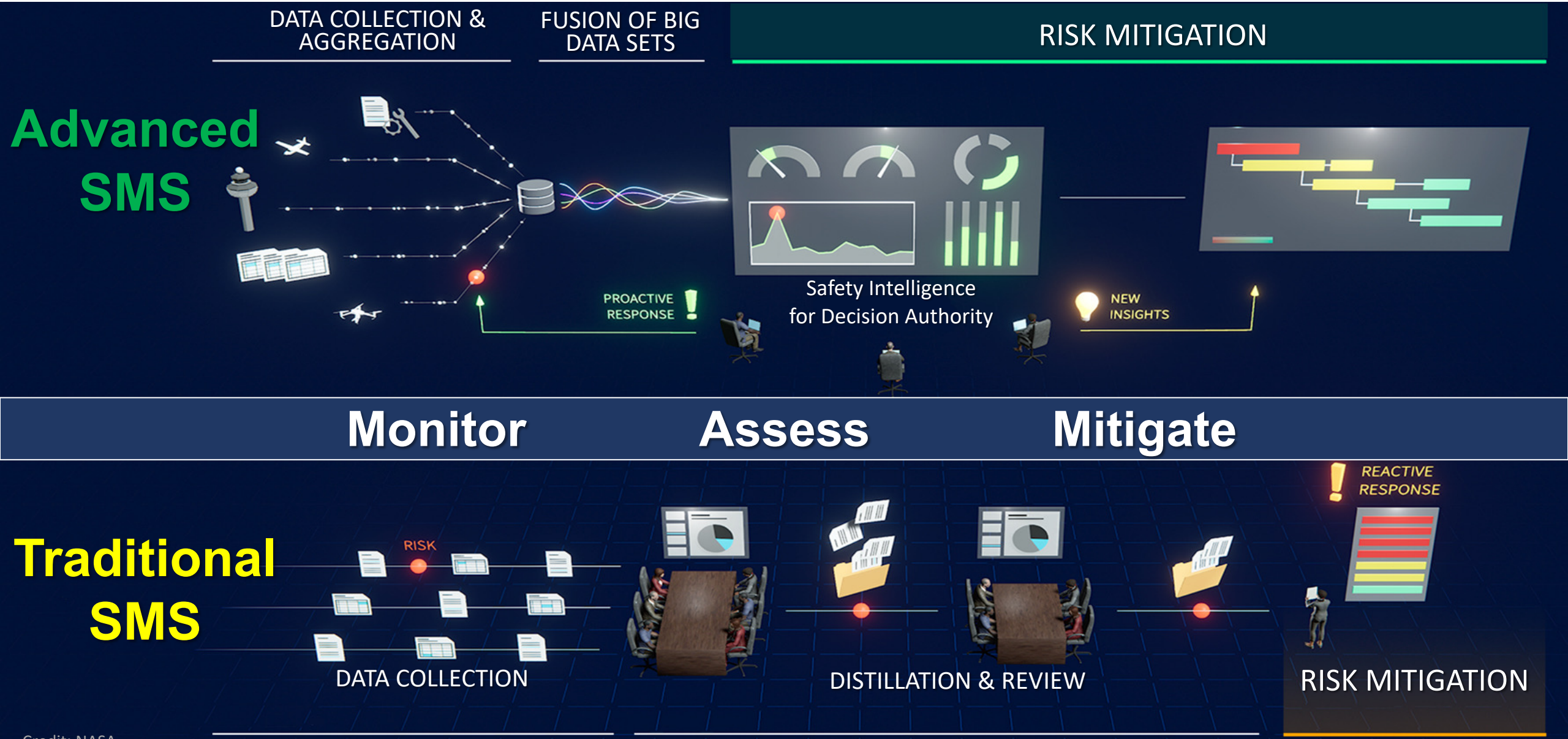
- ML/AI Anomaly Detection
- Predictive Risk Assessment
- Multi-Risk Safety Prognostics
- Natural Language Processing
- Digital Twin Assessments
- Data Exchange Architecture
- Digital Information Service Integration

- Pre-Flight Mitigation
- In-Flight Mitigation
- Post-Flight Mitigation
- Re-Design Consideration

- Design Assurance for AI-enabled systems
- Overarching Properties
- Human Autonomy Teaming

Figure from FAA AC No: 120-92B, Safety Management Systems for Aviation Service Providers

Modernization of SMS



Credit: NASA

Q&A

Dr. Kyle Ellis

Project Manager

NASA System-Wide Safety Project

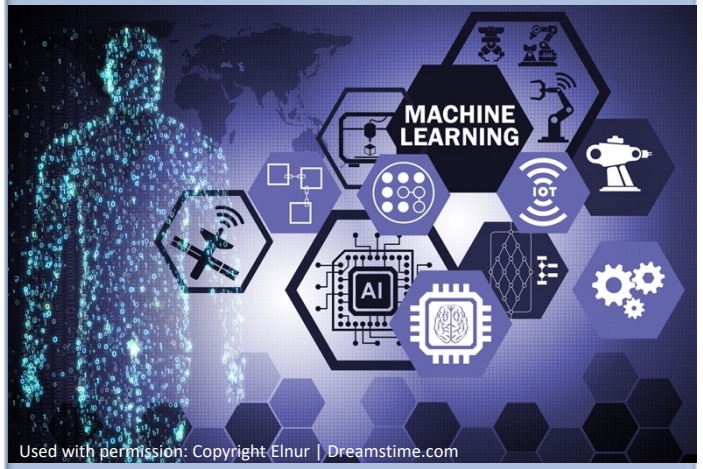
Aeronautics and Space Engineering Board

NATIONAL ACADEMIES *Sciences Engineering Medicine*

System-Wide Safety

Determining Safety Needs for Aviation Transformation

Developing New and Improved Safety Solutions



Used with permission: Copyright Elnur | Dreamstime.com

Disseminating Safety Knowledge and Technology


Used with permission: Copyright Sdecoret | Dreamstime.com

Sustainable aviation transformation through convergence of economic, environmental, and safety technology.

Credit: NASA