The Adaptable and Resilient Safety System:

The Human Factor in Future In-Time Aviation Safety Management Systems

https://www.nasa.gov/directorates/armd/aosp/sws/

AIAA Aviation Forum 2024

AHMT-05, Human-Machine Teaming: Decision Support Tools and Interfaces

AVIATION FORUM

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NASA

Paul Krois, Ph.D.
Senior Technical Subject Matter Expert

System-Wide Safety Project
Airspace Operations and Safety Program

Aviation Safety—Where We Are

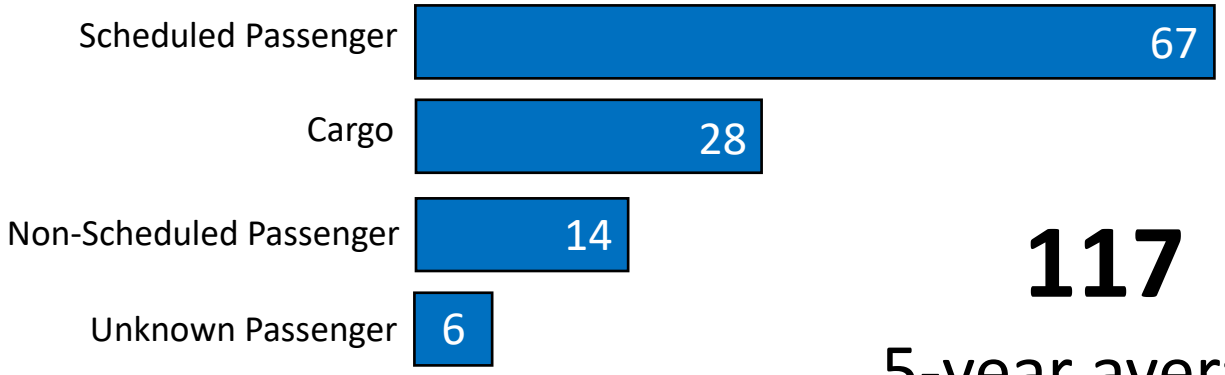
System Wide Safety

Source: https://aviation-safety.net/database/2022-analysis

115 Accidents

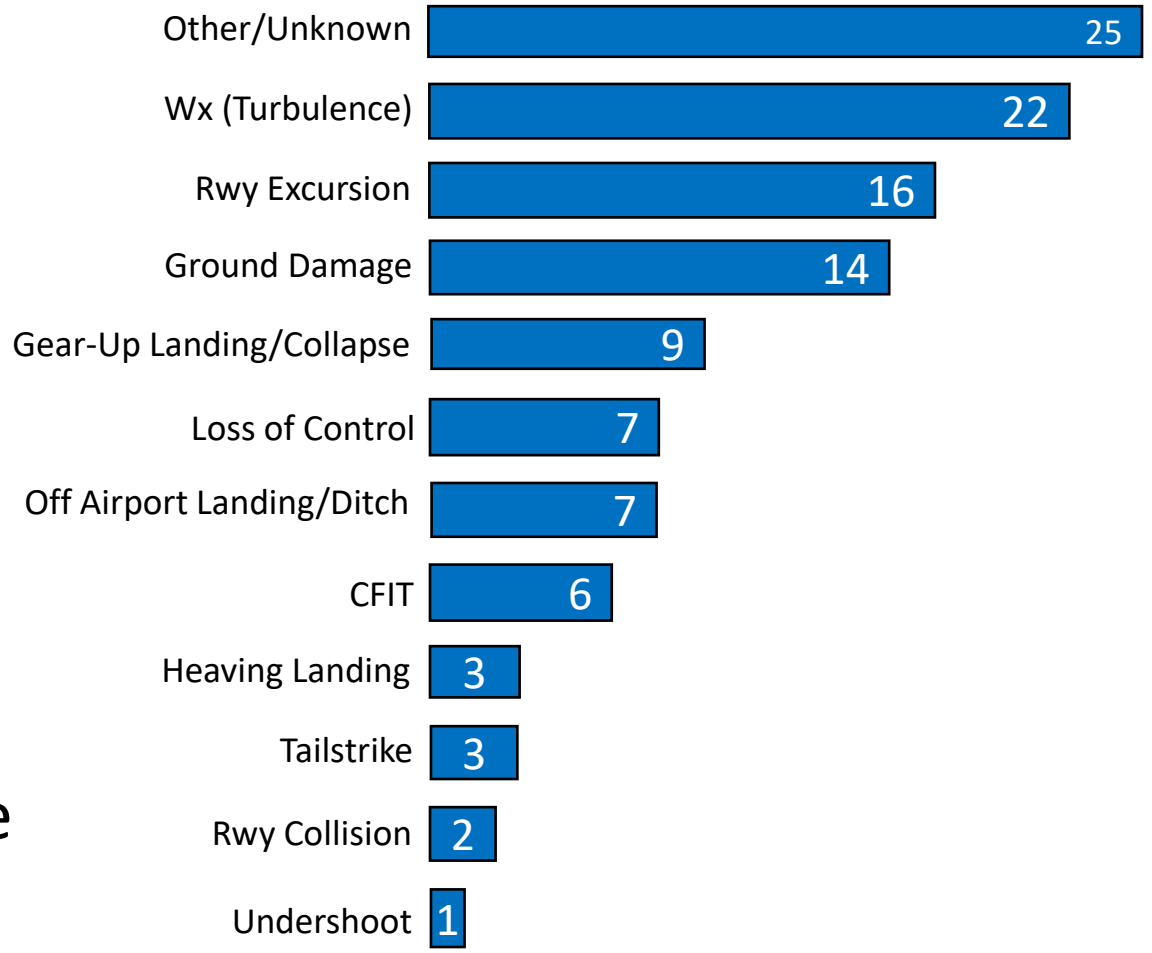
233 Fatalities

4 Ground Fatalities



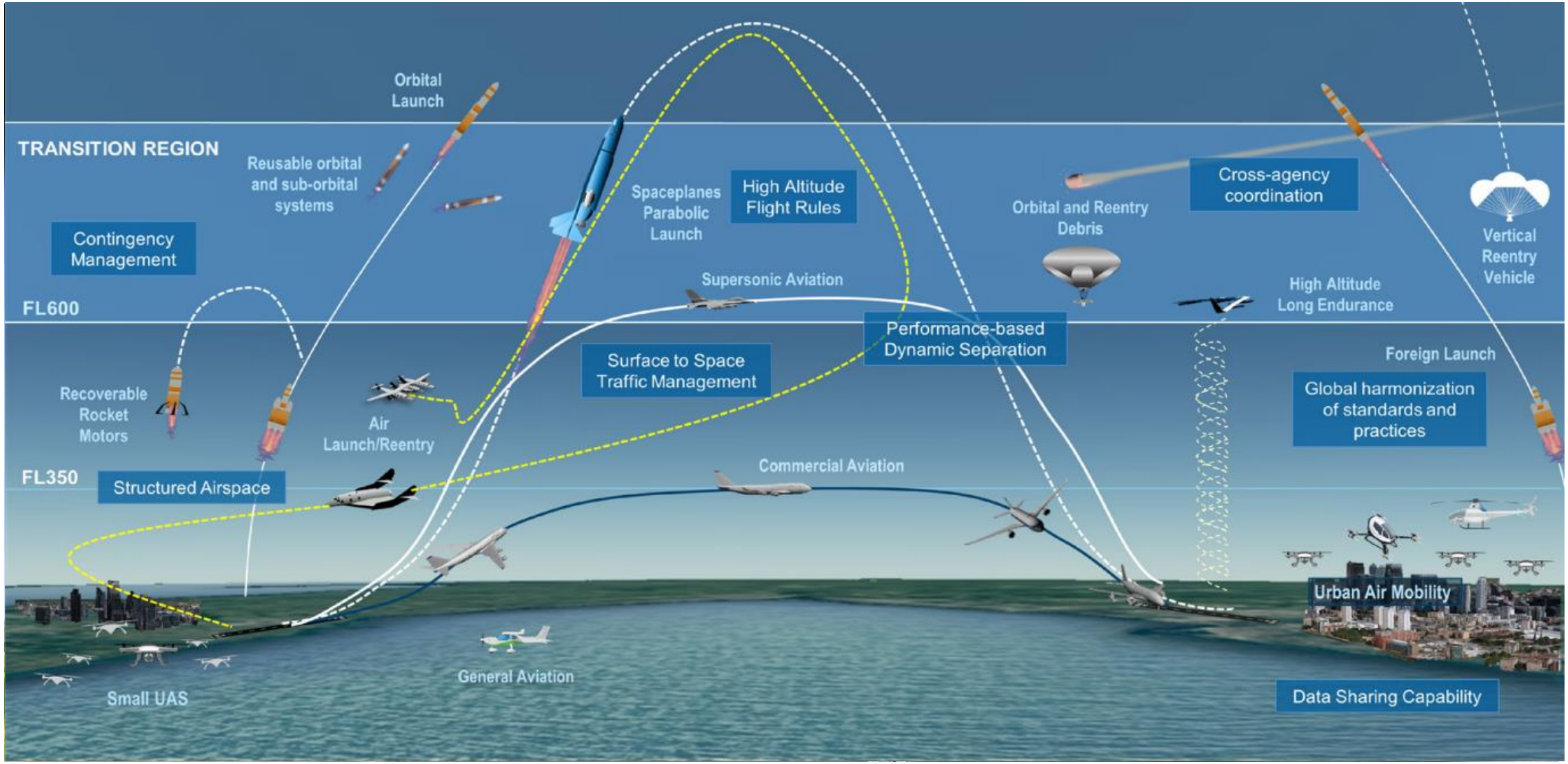
117

5-year average
(2017-2022)



Future Air Transportation System

System Wide Safety



Credit: FAA

Air Transportation System Vision

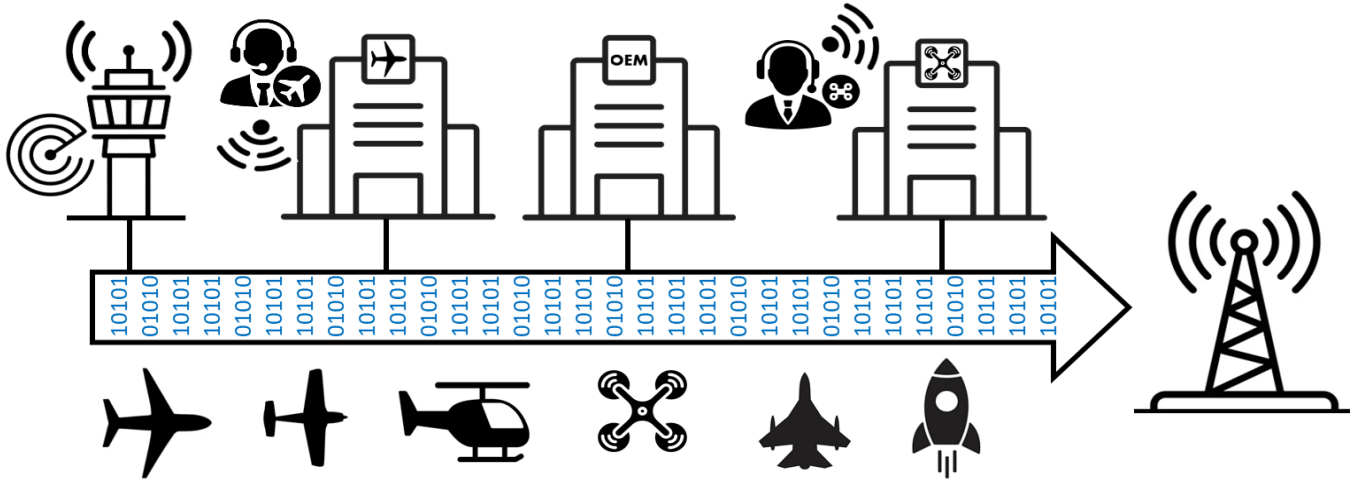
System Wide Safety

Credit: NASA

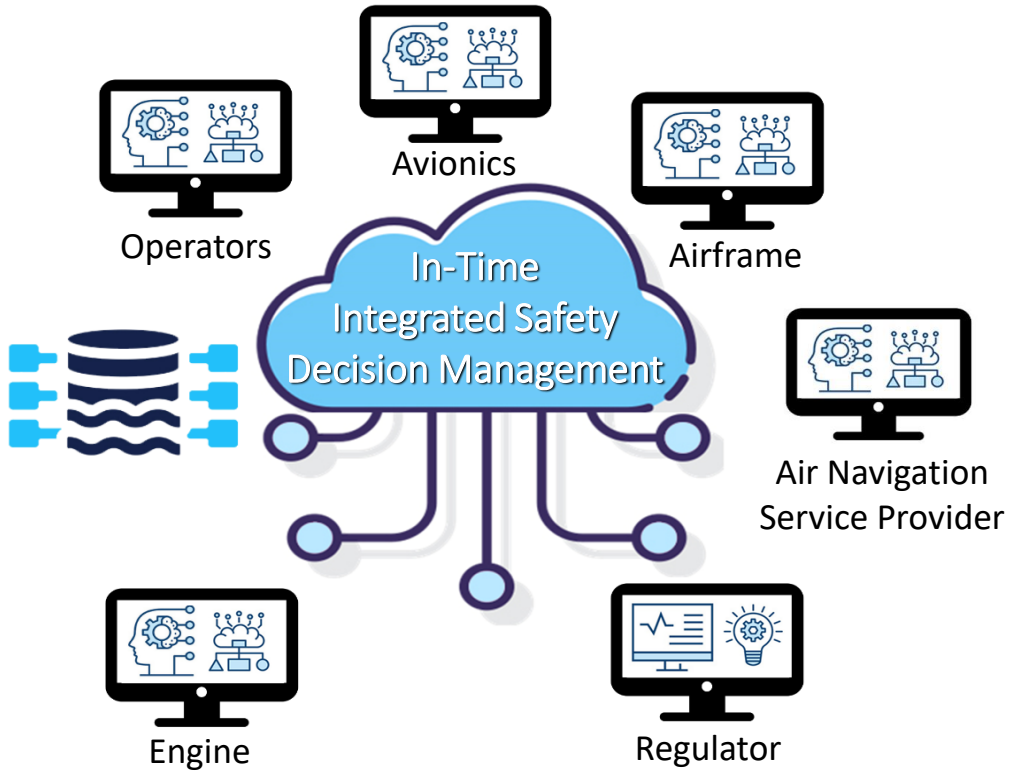
In-Time Integrated Safety Management

System Wide Safety

- System-wide safety risk management analysis to understand when total risk in the Info-Centric and Sky for All NAS is unacceptable through a process to tailor safety requirements for diverse operations and new technologies
- Activities and automated/automation support for an integrated safety monitor, assess, mitigate, and assurance perspective shared among relevant stakeholders and more extensive, complex data-driven/-informed safety decisions



In-Time Data Sharing and Alerting

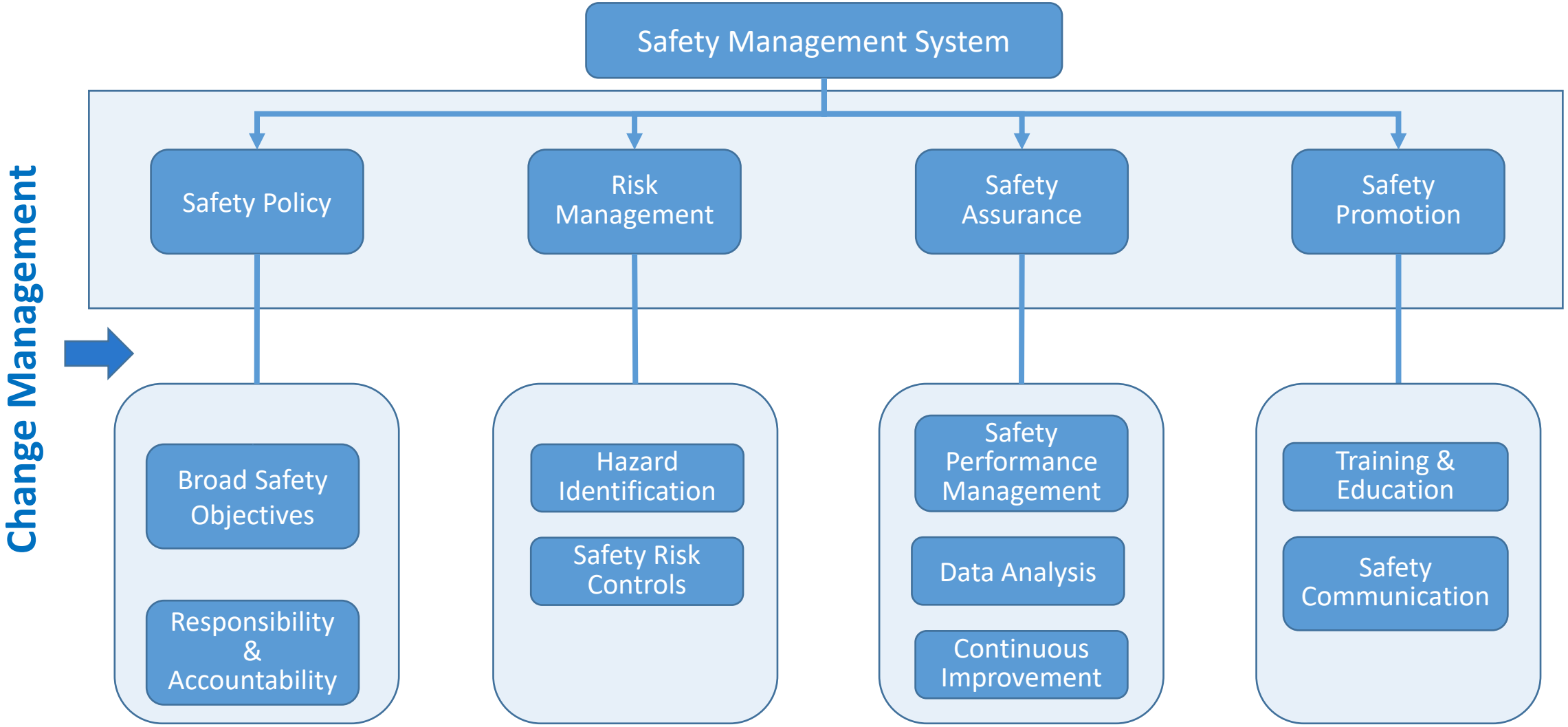


Credit: NASA (adapted FAA graphic)

ICAO – Safety Management System

System Wide Safety

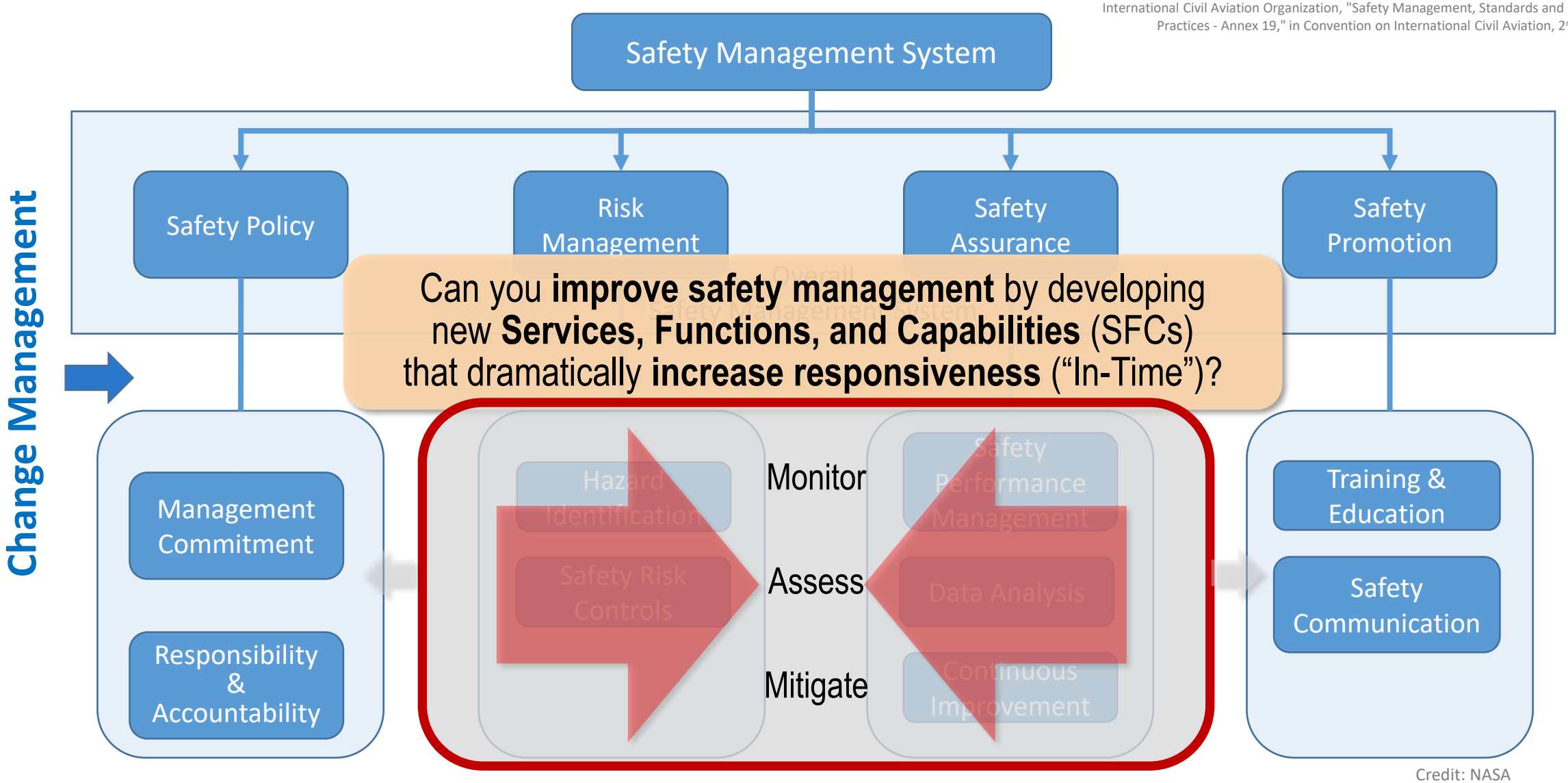
International Civil Aviation Organization, "Safety Management, Standards and Recommended Practices - Annex 19," in Convention on International Civil Aviation, 2nd Edition, 2016



In-Time Services, Functions, and Capabilities

System Wide Safety

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

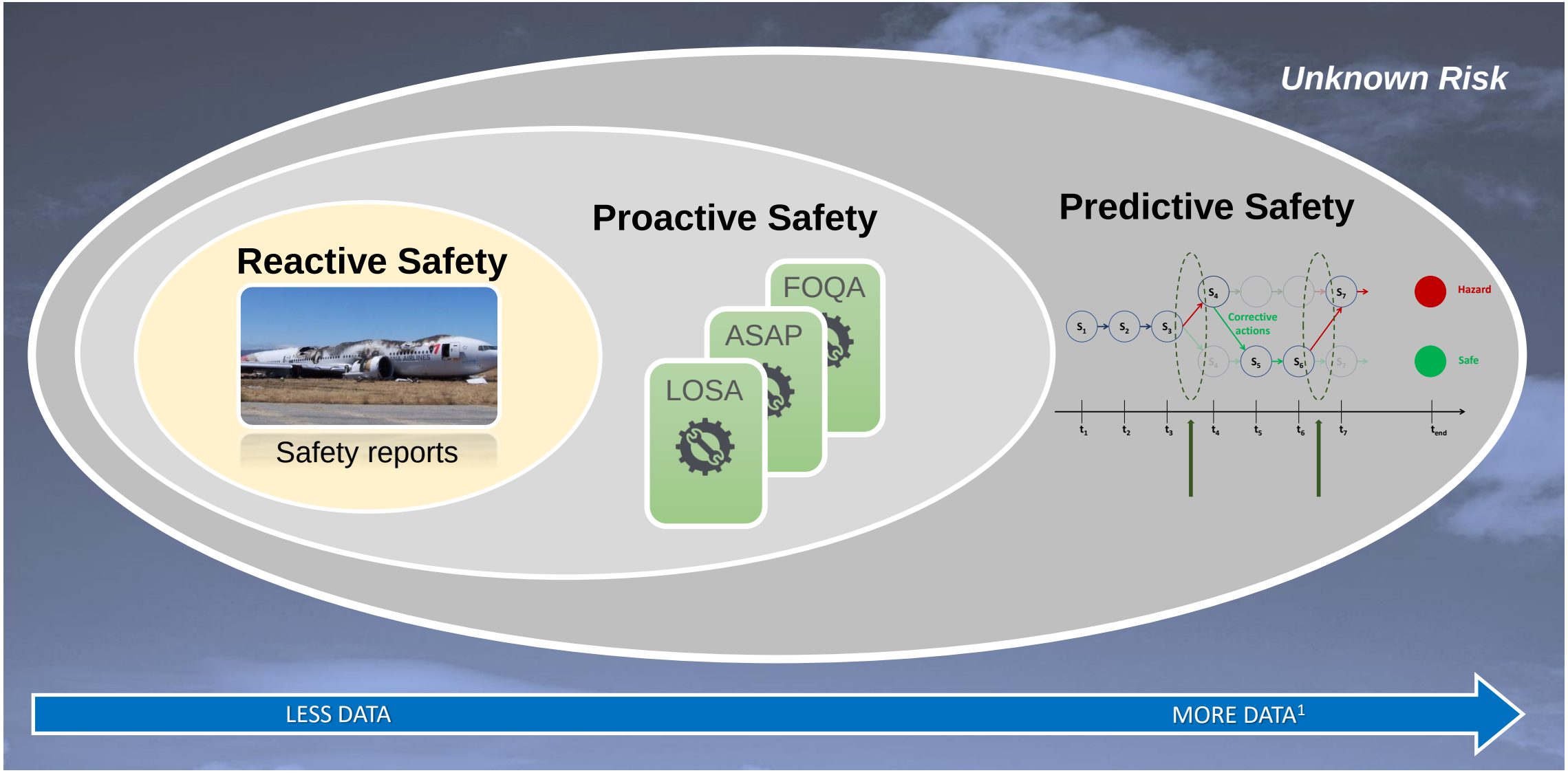


Credit: NASA

Ref: National Academies, In-Time Aviation Safety Management: Challenges and Research for an Evolving Aviation System, 2018.

Progression of Safety Intelligence

System Wide Safety

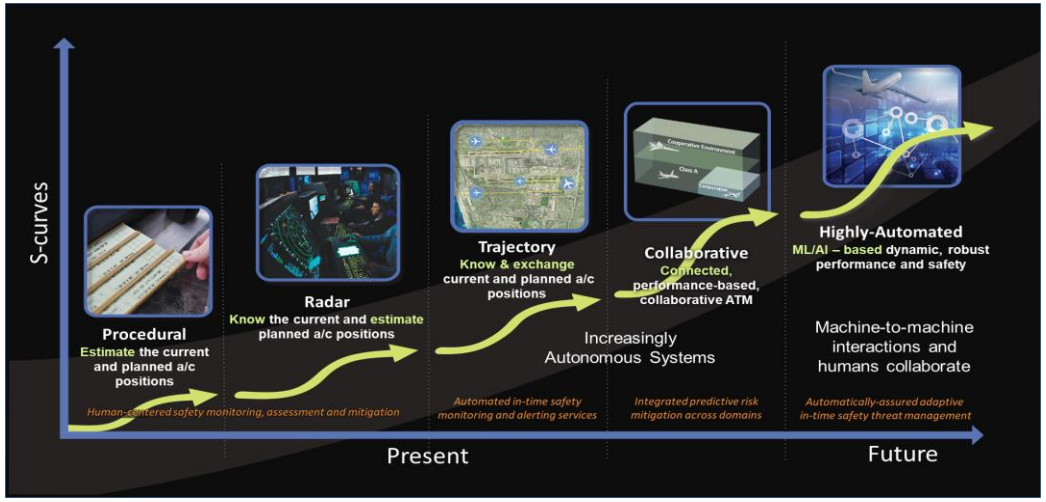


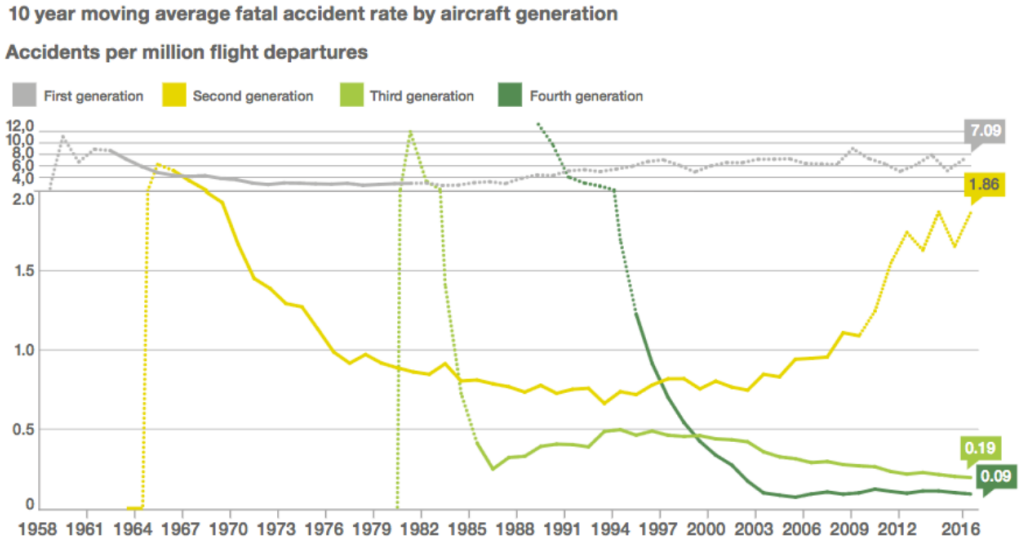
[1]More data volume, complexity, and types

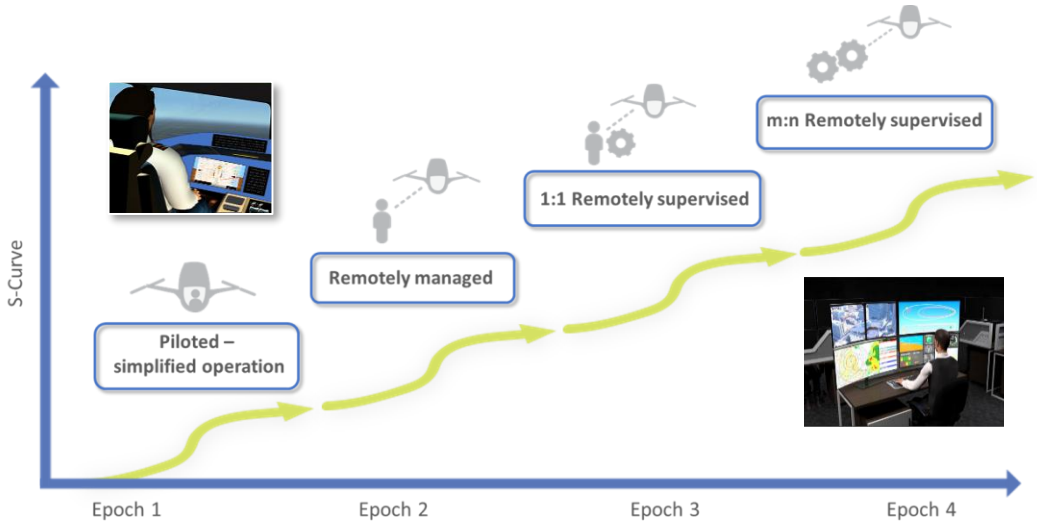
Credit: NASA

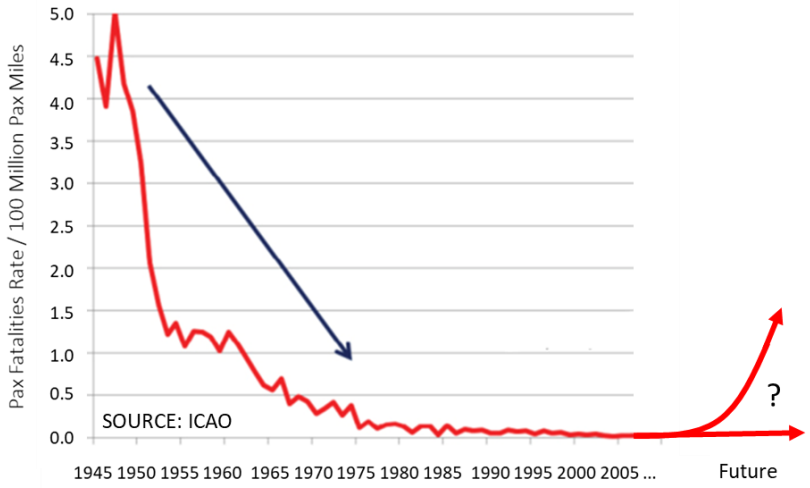
New Technology and Operations Introductions

System Wide Safety









Source: Feary, M. (2018). A First Look at the Evolution of Flight Crew Requirements for Emerging Market Aircraft. AIAA Aviation 2018.

Multi-Agent Adaptive & Resilience Safety Systems

System Wide Safety

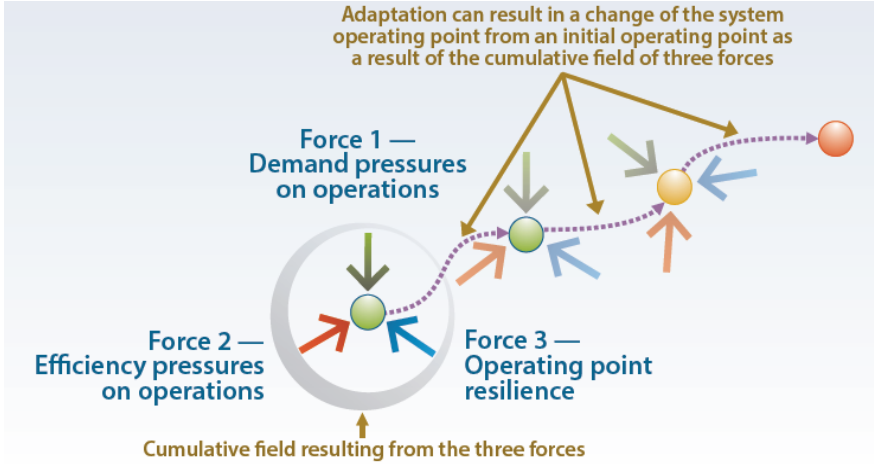
Sociotechnical resilient and adaptive systems can be characterized:

Systems and people that –

- Know what to do – addresses the actual
- Know what to look for – addresses the critical
- Know what to expect – addresses the potential
- Know what has happened – addresses the factual, learning from past and predicting the future

What they look like –

- Appropriate information provided to human to enable and ensure awareness of above
- Clearly defined and communicated roles and authority levels (including back-ups)
- Supported communication among agents
- Flexible function allocation among humans and automated agents



Three Forces Model of System Adaptation[1]

The human represents the only true adaptive agent in the modern air transportation system today

Image Credits: Flight Safety Foundation / NASA[1]

[1] Funded under NASA cooperative agreement 80NSSC21M0187

Human Factor Challenges

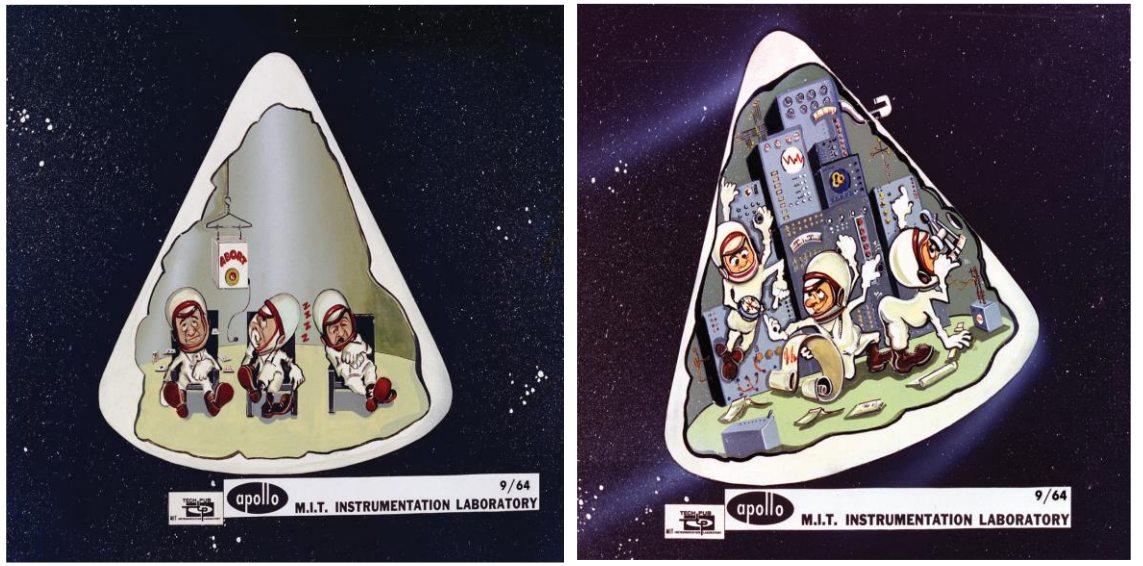
System Wide Safety

- Historically, design of safety systems reflected more what technology could do at design time with remainder of tasks being off-loaded/given to humans, to include supervisory control monitoring responsibilities of the overall system; sometimes termed “function allocation by substitution”.

- Systems evolve over time to become ever more capable, with added and/or expanded functionality, that can tax the human ability to interpret, understand, and act on data and actions recommended by such systems.

- The increase in ML/AI-based safety SFCs and safety systems may acerbate this problem for traditional actors/agents but have substantial potential to extend to other operators (e.g., future safety data analysts/scientist or multi-vehicle control (m:N) fleet managers).

- Significant potential human factors challenges exist that should be addressed early in design system lifecycle.



Credit: NASA/Draper

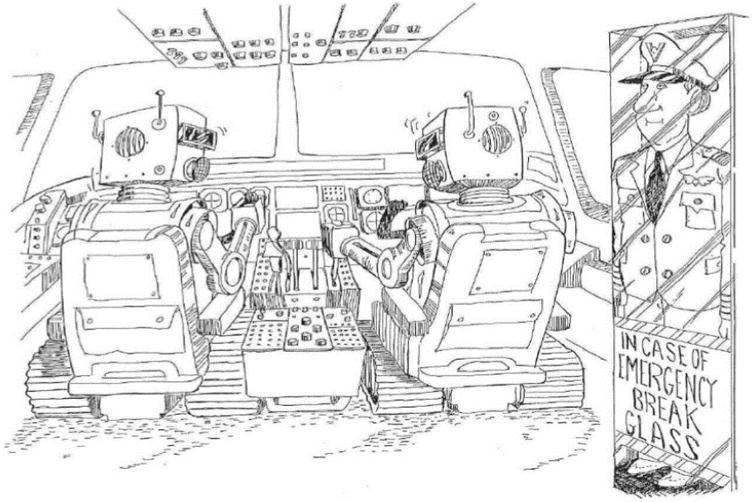
Human Factor Design Goal

System Wide Safety

- History has shown with safety technologies that are not designed optimally for human use that can lead to concerns of misuse, disuse, and abuse.

- For example, “clumsy automation design” have resulted in issues of complexity, brittleness, opacity, literalism, and increased training requirements as well as many human-system interaction issues (e.g., data overload, skill degradation, high monitoring requirements, coordination challenges, and trust/overreliance on opaque but seemingly highly reliable automated system).

- The design goal should be a symbiosis between humans and machines where they can work together better - a design paradigm shift in thinking offered by human-machine teaming.



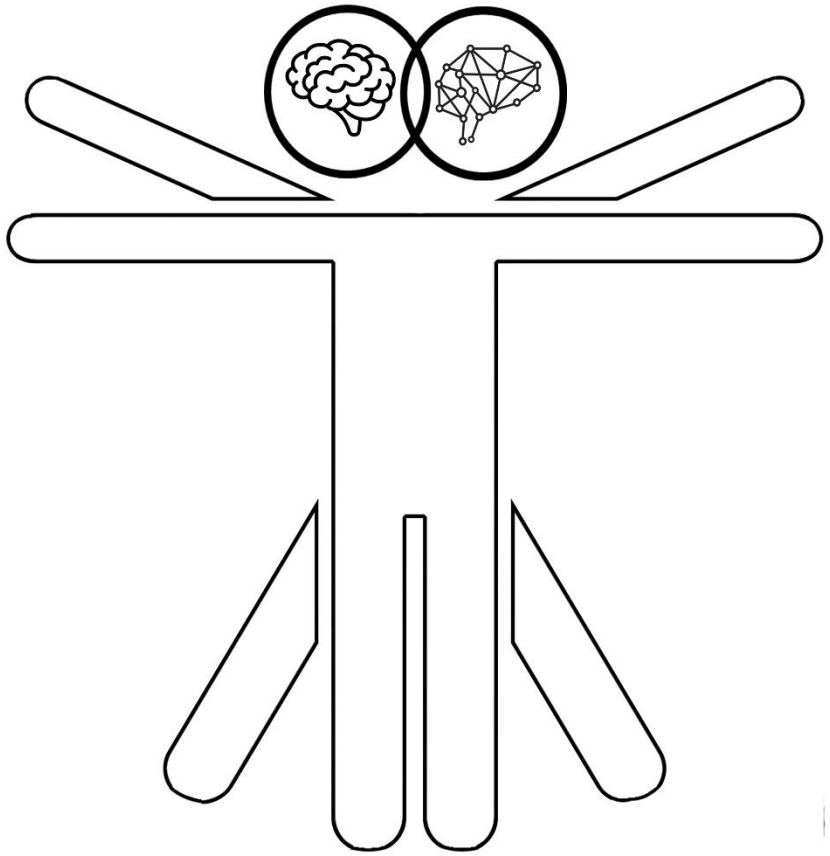
Retrieved from Fong (ARC-E-DAA-TN62415)

Credit: Deloitte[1]

[1] Image - creative commons (17 U.S. Code § 107.Limitations on exclusive rights: Fair use). Deloitte provides open access to graphics and content under “use of content” https://action.deloitte.com/insight/3239/ai-success-factor-human-machine-teaming

Human Factor R&D Focus Areas

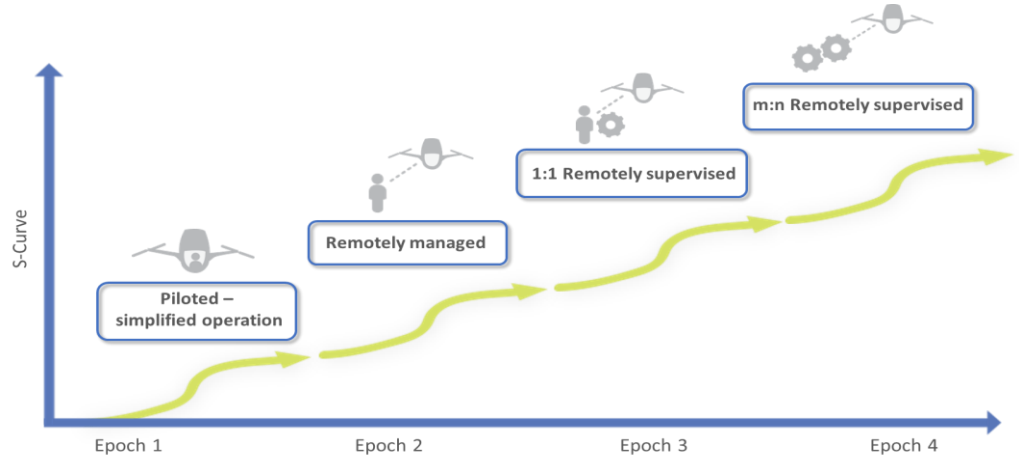
- New human roles and responsibilities
- New information and cognitive requirements
- Human-system interaction and coordination
- Human-system integration/human-machine teaming
- System interdependencies/organizational factors



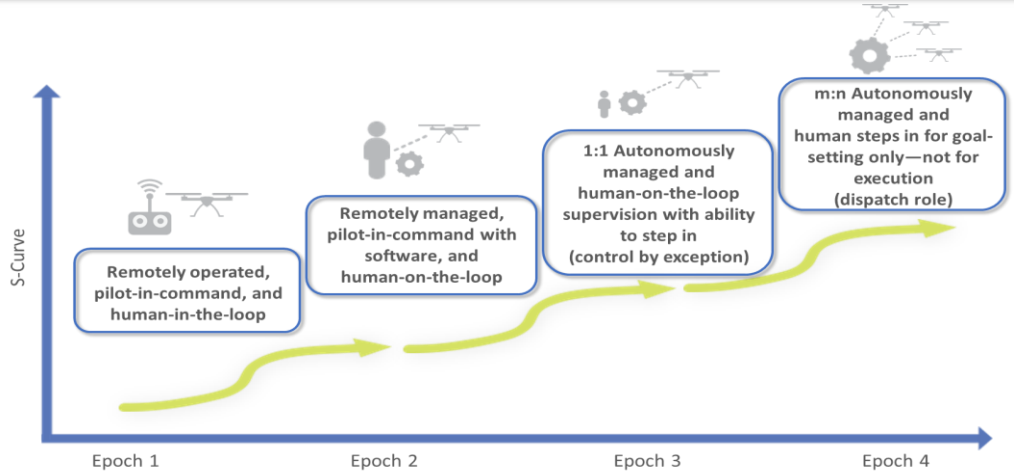
Credit: NASA

New Human Roles and Responsibilities

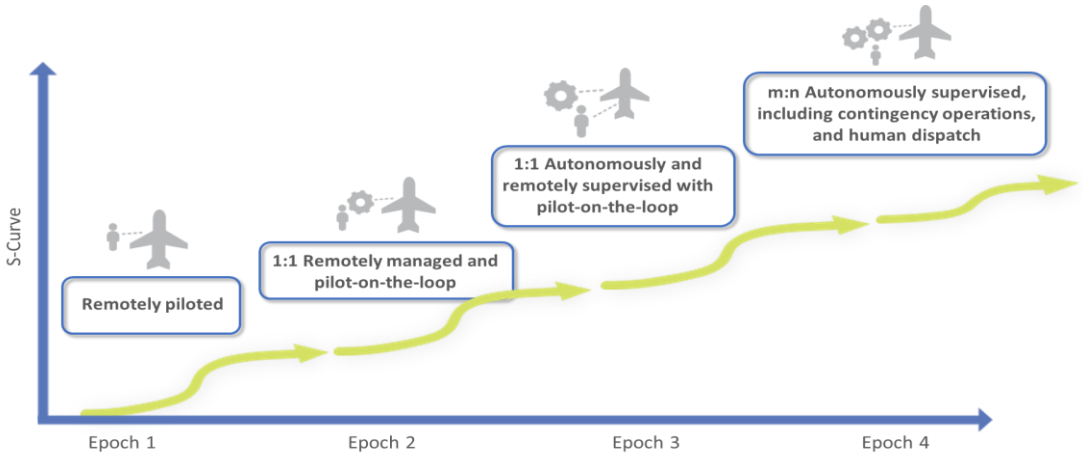
System Wide Safety



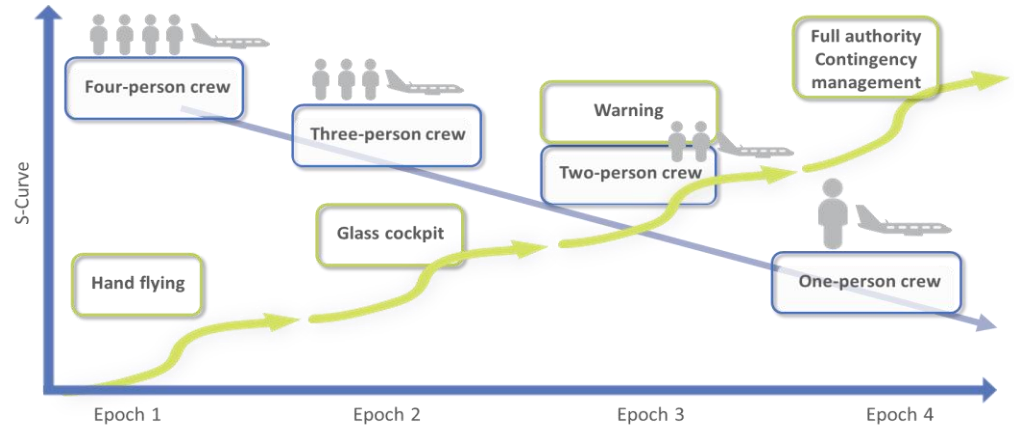
Small Unmanned Aircraft Systems



Advanced Air Mobility/Urban Air Mobility



Small-, Medium-, and Large-Size Cargo



Automation Augmented Crew/Reduced Crew Operations

Select Examples

Credit: Parimal Kopardekar/NASA

New Information and Cognitive Requirements

System Wide Safety

- New Cognitive and Attentional Demands
- New Forms of Error
- New Data Types and Advanced Data Analytics
- New Ways of Human-System Information Processing
- New Training Needs
- New Interfaces and Management of Information

Remote Supervisory Operations

Simplified Vehicle Operations

Images Credit: NASA

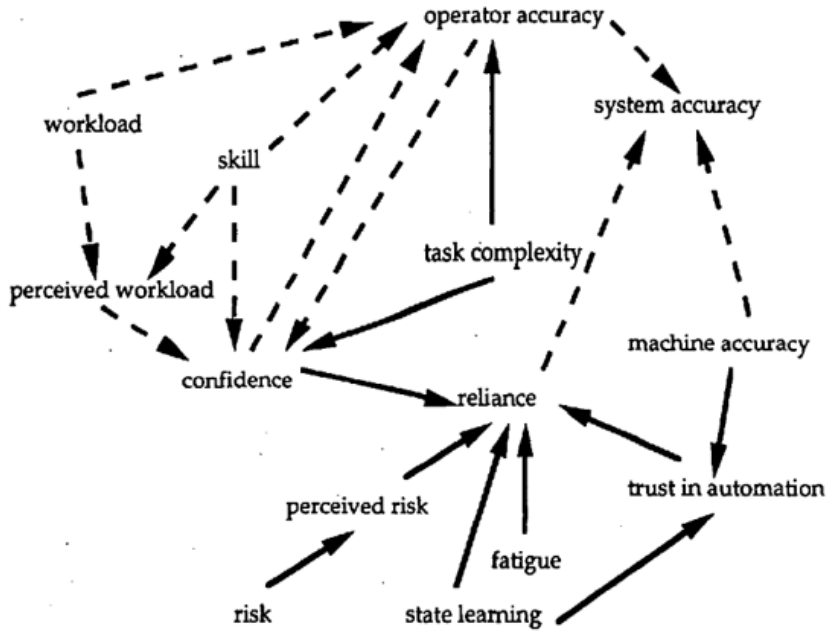
Human-System Interaction and Coordination

System Wide Safety

- Human-Automation/-Autonomy Interaction
- Human-Machine/-System Trust

	ROLES			
LEVEL OF AUTOMATION	MONITORING	GENERATING	SELECTING	IMPLEMENTING
Manual Control	Human	Human	Human	Human
Action Support	Human/Computer	Human	Human	Human/Computer
Batch Processing	Human/Computer	Human	Human	Computer
Shared Control	Human/Computer	Human/Computer	Human	Human/Computer
Decision Support	Human/Computer	Human/Computer	Human	Computer
Blended Decision Making	Human/Computer	Human/Computer	Human/Computer	Computer
Rigid System	Human/Computer	Computer	Human	Computer
Automated Decision Making	Human/Computer	Human/Computer	Computer	Computer
Supervisory Control	Human/Computer	Computer	Computer	Computer
Full Automation	Computer	Computer	Computer	Computer

Human-Automation Interaction and Roles[1]



Use, Misuse, Disuse, Abuse[2]

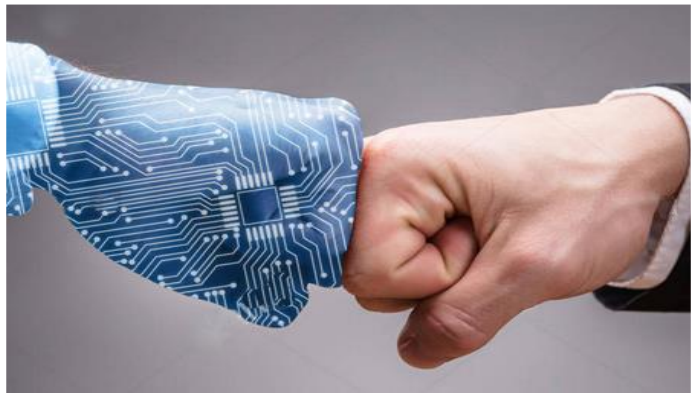
[1]Endsley, M. R., & Kaber, D. B. (1999). Level of automation effects on performance, situation awareness and workload in a dynamic control task. Ergonomics, 42(3), 462-492.

[2]R. Parasuraman and V. A. Riley, "Humans and automation: Use, misuse, disuse, abuse," Human Factors, vol. 39, pp. 230–253.

Human-System Integration/Human-Machine Teaming

System Wide Safety

- Human-System Integration
- Human-Machine Teaming



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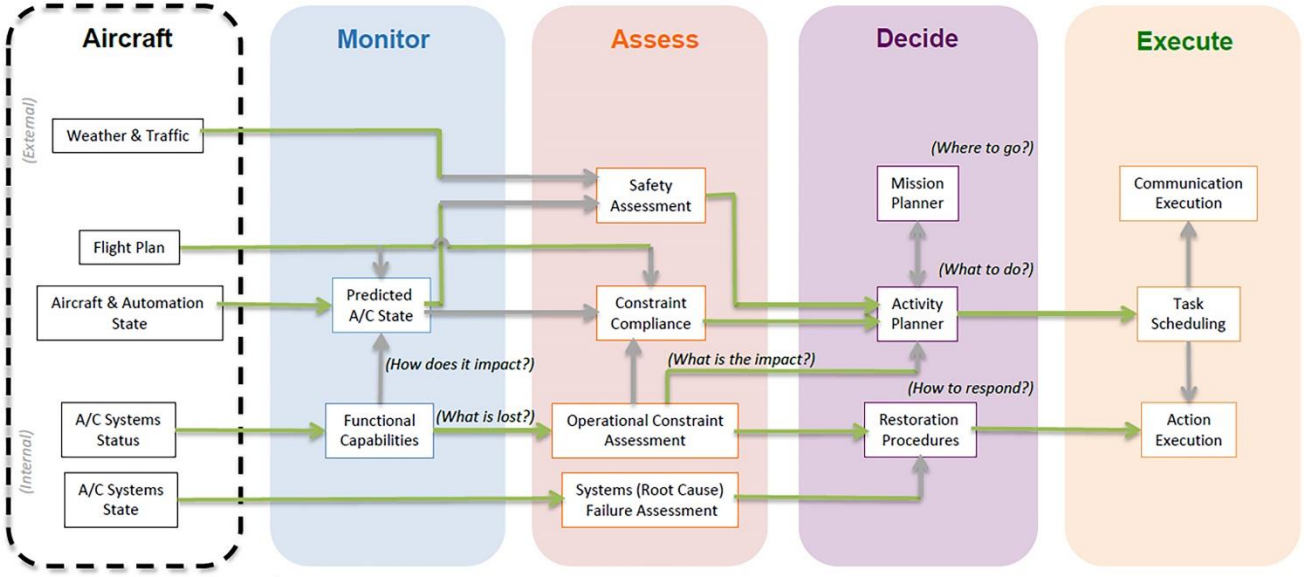


General Human-Autonomy Teaming Framework (Example)[1-5]

[1]Conducted under the Aviation Operations and Safety Program (AOSP), Safe Autonomous Systems Operations (SASO)

[2]Aponso, B.L. (2017). The Challenges of Human-Autonomy Teaming. SAE/NASA Autonomy and Next Generation Flight Deck Symposium. April 18-19, 2017. Slide 18.

[3] Kopardekar, P., Graves, S., & Pevot, T. (2016). Deep Dive Presentation for ARTR. August 2, 2016. Slide 16.

[4] Aponso, B. (2017). HAT Tricks: Understanding Human Autonomy Teaming through Applications. Slide 10

[5] Bailey, R.E., & Aponso, B.L. (unpublished). Concept of Operations for Safe and Efficient Crew-Autonomy Teaming Technologies.

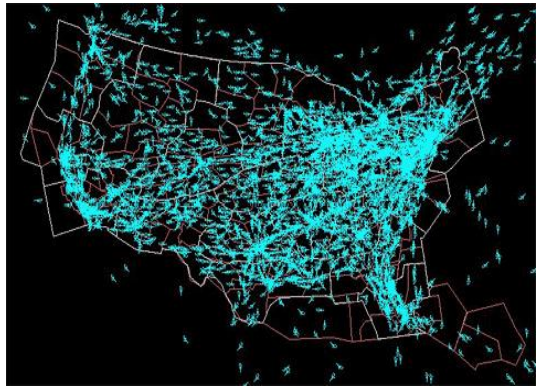
System Interdependencies/Organizational Factors

System Wide Safety

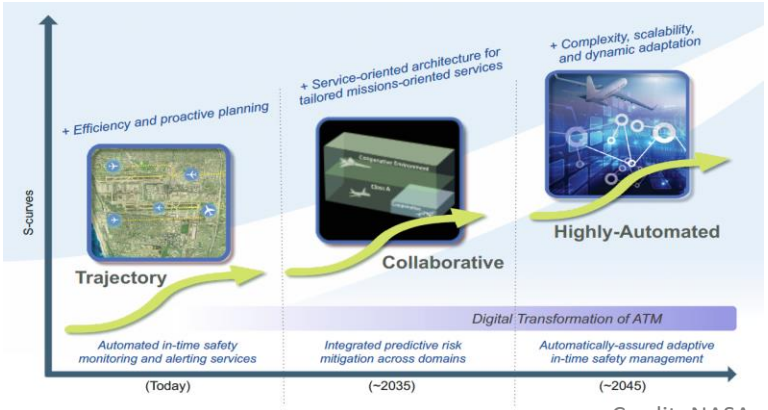
- Design Throughout System Lifecycle
- Taking a System-Wide Perspective
- Examining Influence of Organizational Factors

Credit: Flight Safety Foundation/NASA

Four Operational Resilience Capabilities[1]



Credit: FAA



Credit: NASA

Credit: NASA

Transformation of the National Airspace System

[1] Flight Safety Foundation / NASA. Funded under NASA operative agreement 80NSSC21M0187

New Opportunities, New Challenges

- Examined common and unique human factors and human-system interaction challenges involved in future in-time integrated safety management and safety SFC design.
  - New human roles and responsibilities
  - New information and cognitive requirements
  - Human-system interaction and coordination
  - Human-system integration/human-machine teaming
  - System interdependencies/organizational factors
- Advocated for design goal of humans and machine symbiosis - better by teaming and working together.
- Some guidance exists, but significant research needs remain to include human teaming with potentially adaptive and resilient, highly complex automated/increasingly autonomous in-time integrated safety management systems and associated operational and vehicle safety SFCs.

Credit: NASA

Credit: NASA

Future "Sky for All" Is "Safe for All"

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