In-time aviation safety management systems for increasingly autonomous wildland firefighting operations

Dr. Natasha Neogi
System Wide Safety Project
Airspace Operations and Safety Program
NASA Aeronautics Research Mission Directorate
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SWS Overview with TC5 Focus

Safety Demonstrator Series:
Operational demonstration of and recommendations for requirements and standards necessary to monitor, assess, and mitigate risks to assure safety in disaster-oriented operations.

Operational Safety (Thrust 5)

- TC-1: *Predictive Terminal Area Risk Assessment*
- TC-2: *IASMS SFC Development for Emerging Operations*
- TC-6: *IASMS for Traditional Aviation Operations*

Current Day

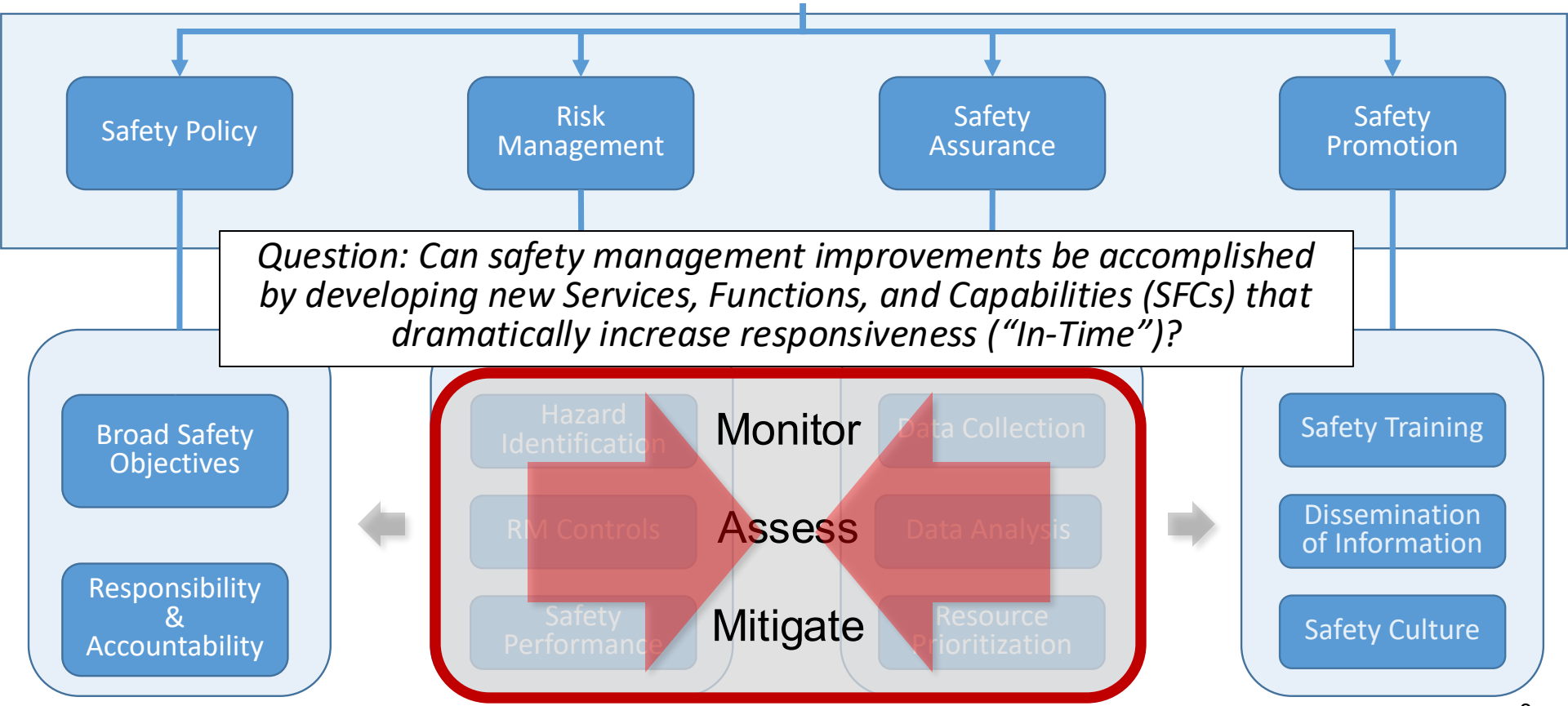
- TC-3: *V&V for Commercial Operations*
- TC-4: *Complex Autonomous Systems Assurance*

Design Safety (Thrust 6)

- TC-5: *Safety Demonstrator Series for Operational IASMS*

Transformed NAS with IASMS

In-Time Aviation Safety Management (IASMS)



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

Scheduled Progression

SD-1 (FY 23) — Wildfire Fighting

- ! HIGH — Rural and partially evacuated area
- LOW-MODERATE — Intensive HMI and lack of commercial flights
- ? LOW-MODERATE — Unknown location of fire; poor visibility

Environment: Low Visibility, Smoke...

Vehicle & Mission: sUAS, mid-size UAS/ Short Range

SD-2 (FY 27) — Hurricane Relief and Recovery

- ! MED — Partially evacuated area
- MODERATE — Numerous agencies coordinating multiple relief efforts
- ? MODERATE-HIGH — Unknown state of terrain; poor infrastructure

Environment: Low Visibility, RF/EMF Hazards, Poor Weather…

Vehicle & Mission: sUAS, mid-size UAS, large UAS/ Multiple Days

SD-3 (FY 29) — Emergency Medical

- ! LOW — Urban area
- MODERATE — Regularly scheduled commercial flights
- ? MODERATE — All weather operations

Environment: Urban Airspace, RF/EMF Hazards…

Vehicle & Mission: sUAS, mid-size UAS, large UAS/ Short to Long Range

SD-4 (FY 32) — Urban Disaster Relief

- ! LOW — Urban area
- HIGH — - - - - -
- ? HIGH — - - - - -

Environment: Degraded Infrastructure, RF/EMF Hazards…

Vehicle & Mission: sUAS, mid-size UAS, large UAS/ Multiple Days

! Risk Tolerance Complexity ? Uncertainty

4

Services, Functions and Capabilities

Services and *Functions* enabling new In-Time Safety Assurance *Capabilities*

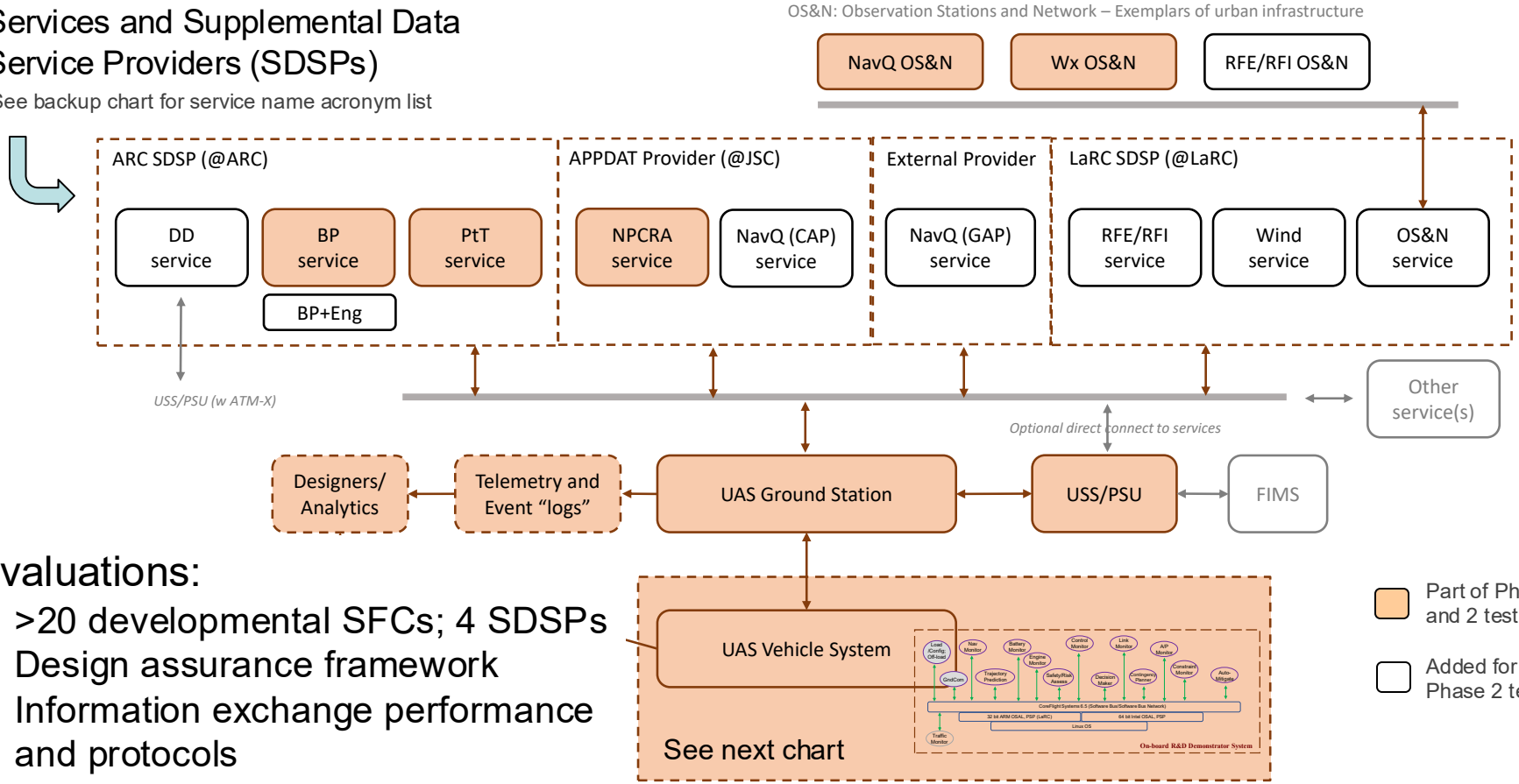
Services
3rd party casualty risk assessment (GRASP)
Navigation quality assessment (NavQ)
Proximity to threat assessment (PtT)
Obstacle collision risk assessment (ROC)
RF environment and interference monitor (RFE/RFI)
Weather/wind monitoring and forecasting (WM; EOSN-Wx; WS)
Airspace dynamic density assessment (DD)
Battery prognostics (BP)
Flight performance assessment service (FPAS)
Aircraft and flight system state telemetry (TM)

Functions
Operator interfaces (3)
Off-line anomaly detectors (using log files)
Onboard: (Configured as indep. RTA framework)
Auto-pilot monitor
Battery health monitor
Constraint monitor (Class B safety-critical)
Contingency select and trigger
Anomaly detector
Real-time risk assessment
Proximity to threat monitor
Traffic detect-and-avoid

Test and Demonstration System

Services and Supplemental Data Service Providers (SDSPs)

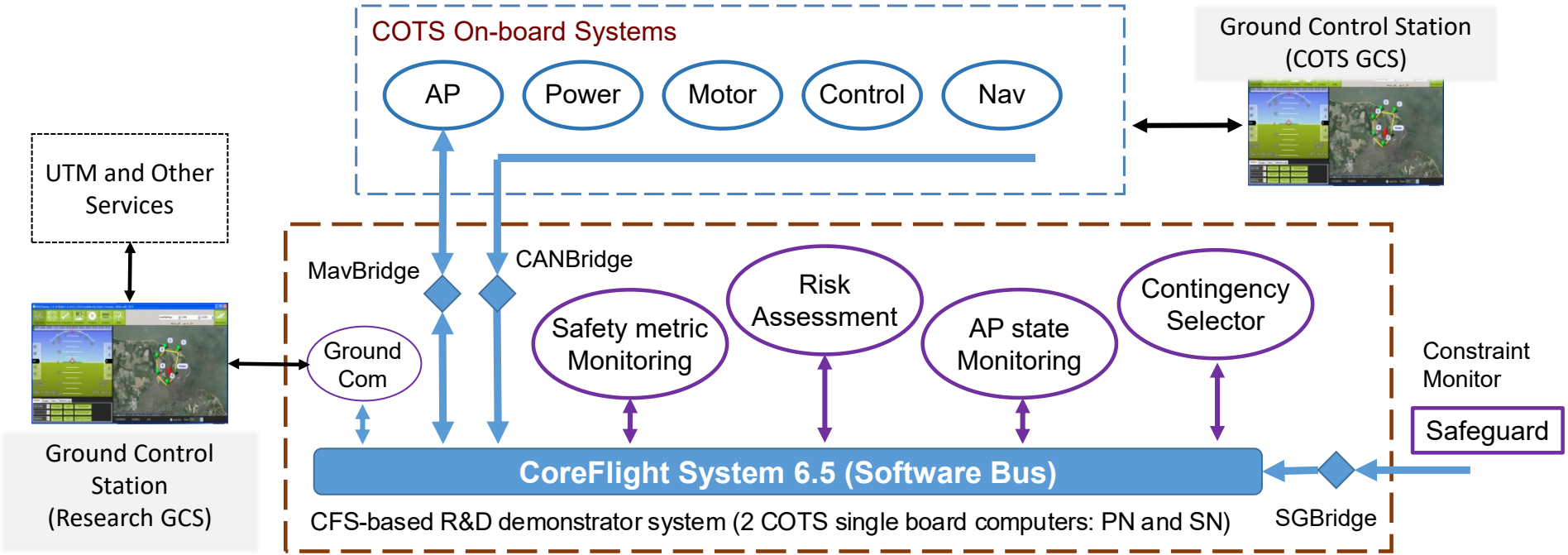
See backup chart for service name acronym list



Evaluations:

- >20 developmental SFCs; 4 SDSPs
- Design assurance framework
- Information exchange performance and protocols

Vehicle System



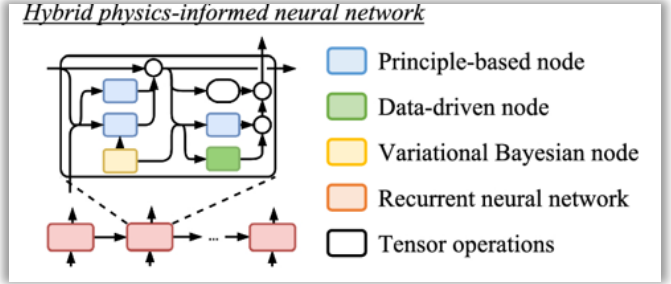
AP – Autopilot; CFS – CoreFlight System; PN – Primary Node; SN – Secondary Node

Battery Prognostic Service

Purpose: Help mitigate hazards arising from control or propulsion system shutdown during flight due to insufficient or loss of battery power. Produce estimates of State Of Charge (SOC) and/or Remaining Flight Time (RFT) at waypoints for pre-flight planning or in-flight rerouting.

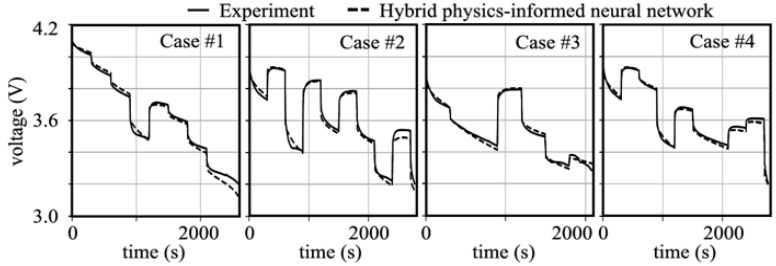
Inputs: Client requests should include:

1) Battery ID
2) Battery model parameters
3) Location or flight plan(s)
4) Alert threshold

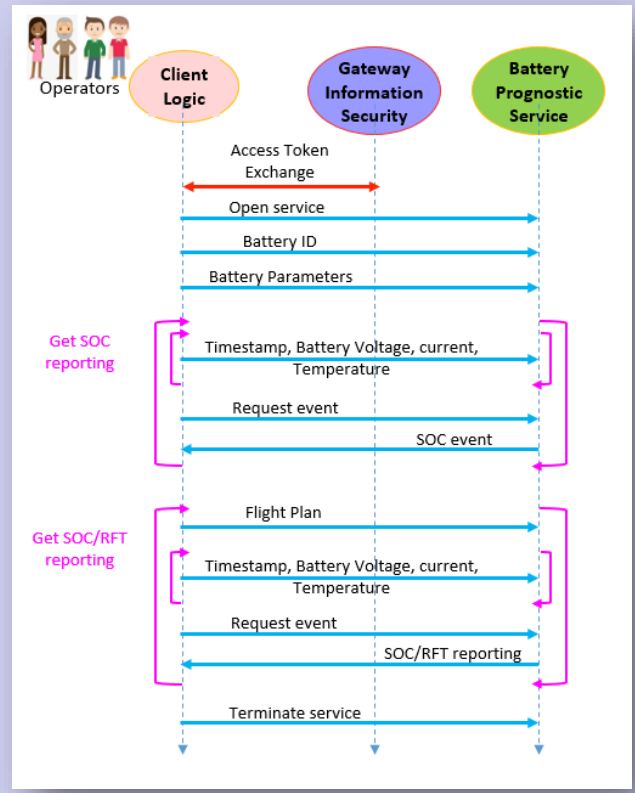


Outputs: Data products can include:

1) Estimated SOC/RFT at current location
2) Estimated SOC/RFT at each waypoint
3) Low margin alerts



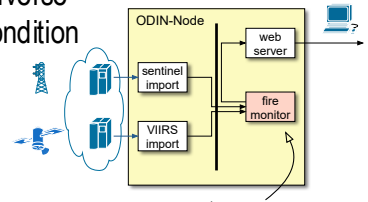
Message Exchange Sequence



Online Data Integration (ODIN)-FIRE Capability

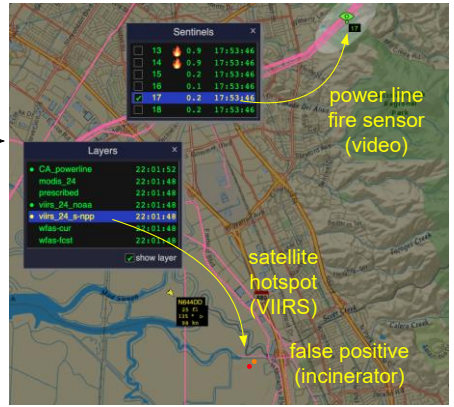
Motivation and Objectives

1) Monitor for adverse condition



autonomous assessment function (correlate input sources)

2) Enhance situational awareness

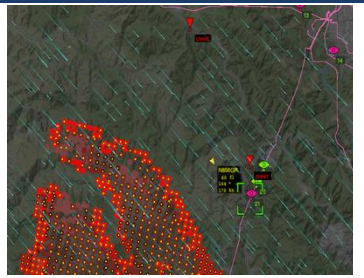


How does ODIN-Fire work?

Uniform architecture
- many application types
- scalable cross-platform

Extensible component library
- data import
- processing
- generic system functions

Open source library to build your projects…

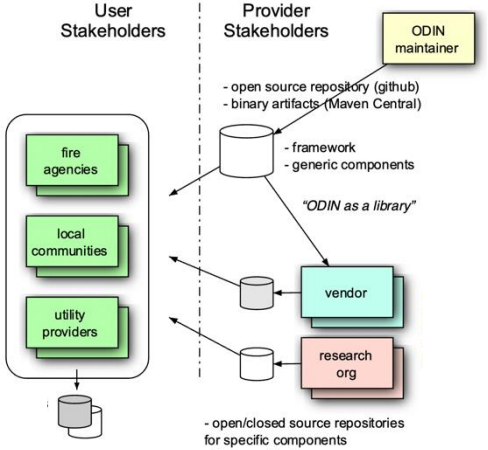


- Powerline sensors (Delphire), VIIR Satellite, Sentinel, live ADS-B Data (and other sources) integrated into ODIN
- Integrated weather data into ODIN via collaboration with WindNinja/USFS Firelabs

What is ODIN-Fire?

Configurable dynamic display of multiple data sources

- Online Data Integration (ODIN): Just need a browser. Open source tool.
- Data sources such as fire/smoke detectors on powerlines, satellite heat data, 3-d buildings, terrain, air traffic assets
- Modelling capabilities such as fire spreading models, weather (wind, ...) …
- Data push capabilities for near real-time updates on single display



Impact

- ODIN Sentinel Alarm application detected fire (Rx burn) and alerted authorities in December 2023 at pilot installation in Ramona, CA.
- SAA with Delphire Inc.
- Collaboration with USFS
- Rocky Mountain Research

Delphire FD3 image of smoke, courtesy of Ramona Sentinel, Jan 9, 2024

Station FireLabs WindNinja micro grid wind forecasts (Spring TFRSAC 2023 presentation

Hurricane Relief & Recovery

Timeline

Timeframe: ~5-10 Years

Missions

Sub-Urban Search and Rescue

Sub-Urban Evactuation Route Assessment

Sub-Urban Flood Damage Estimation

Surveil Coastal Region of Interest

Loss of Navigation System | Navigation Quality Service

Loss of Navigation System | Navigation Quality Service

Loss of Power | Battery Prognostics and Health Monitor Functions

Unsafe Proximity to Traffic | Air Traffic Detect-and-Avoid Function

Loss of C2 / Telemetry Link | RF Environment and Interference Monitor Service

Adverse Weather | Weather/Wind Monitor and Forecast Service

TFR In Place

Flight Outside of Approved Airspace and Flight Envelope | Geofencing Function

Unsafe Proximity to Obstacle/Terrain | Proximity to Threat Service

sUAS Below 400 ft AGL

AutoPilot Malfunction | Autopilot Performance and State Monitor

Loss of Control | Non-Participant Casualty Risk Assessment Function

MONITOR

ASSESS

MITIGATE

In-Time Aviation Safety Management System

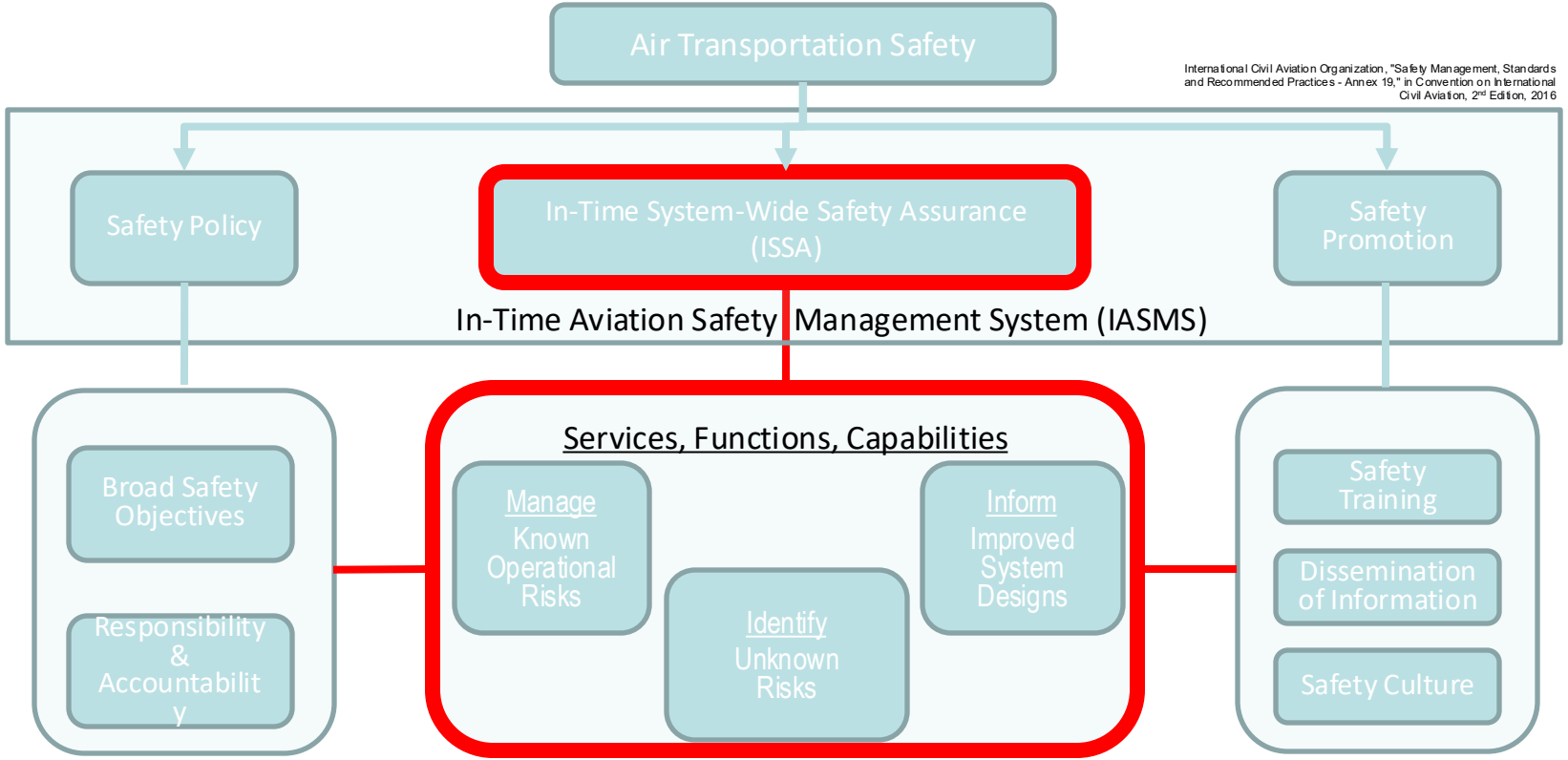
Hazards | SFCs

Questions?

natasha.a.neogi@nasa.gov

Backup

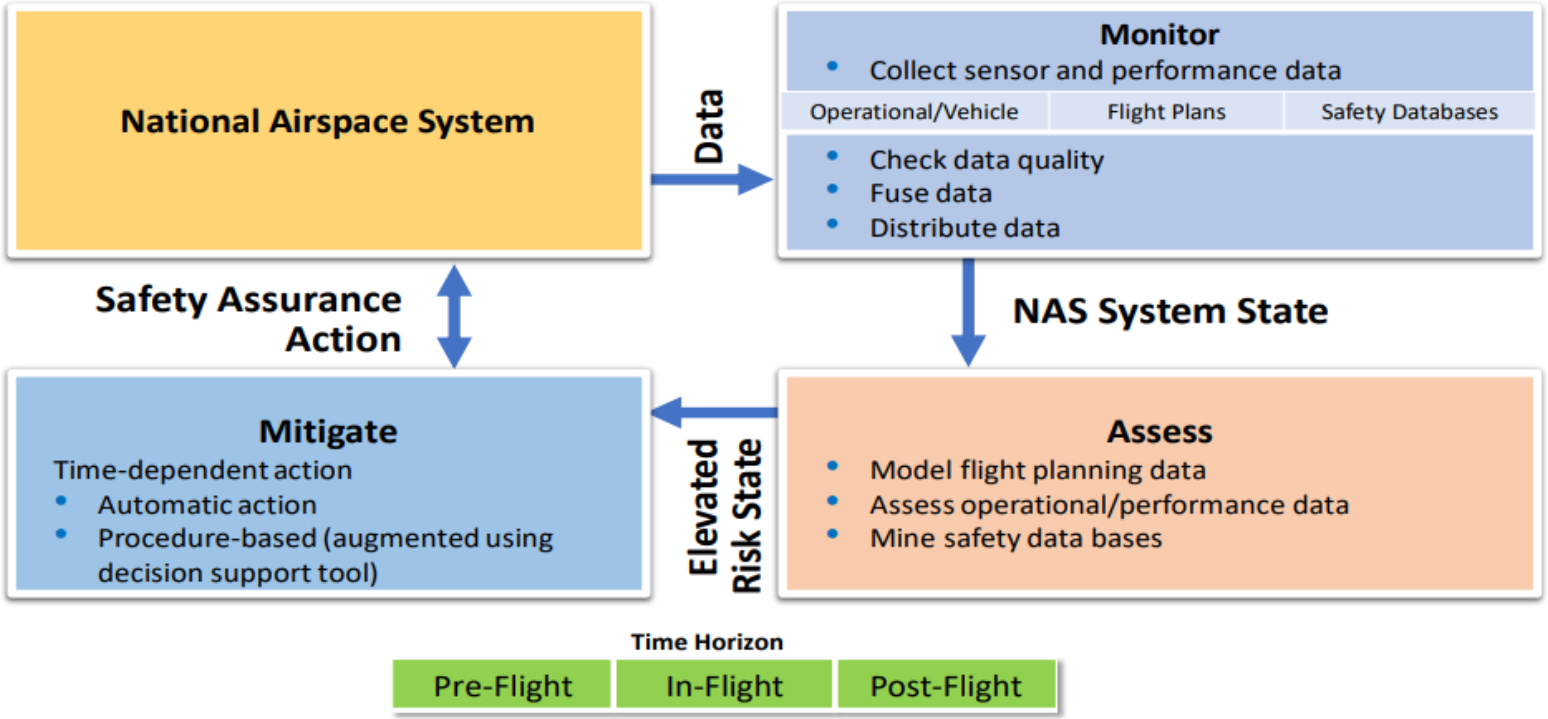
How We Achieve Aviation Safety Tomorrow



(1) Quickly manage known operational risks at scale; (2) Quickly identify unknown risks; (3) Quickly inform design

ConOps and Information Flow

Services and Functions enabling new Capabilities



Ref: [20] Ellis, K., et. al., "A Concept of Operations (ConOps) of an In-time Aviation Safety Management System (IASMS) for Advanced Air Mobility (AAM)," AIAA SciTech 2021.

Service Name Acronyms

DD – Dynamic Density service, a service supporting air traffic management safety by tracking (and forecasting) metrics associated with air traffic density for selected airspace volumes.

BP – Battery Prognostics service, a service that tracks and predicts state-of-charge and remaining useful life of onboard power source(s).

PtT – Proximity to Threat service, a service that tracks and predicts proximity (and safety margins) for high-risk areas near the flight path (e.g., the perimeter of vertical structures).

NavQ CAP – Navigation Quality Corridor Assessment of Positioning service, a service that provides estimates of navigation-related performance measures along a user-specified flight corridor and time window.

NavQ GAP – Navigation Quality Geometric Assessment of Positioning service, a service that provides estimates of navigation-related performance measures over a user-specified coverage and time window.

RFE/RFI – RF Environment and RF Interference service, a service that provides estimates of RF-related performance measures over a user-specified coverage area and forecast period.