Leveraging ASTM Industry Standard F3269-17

Providing Safe Operations of a Highly Autonomous Aircraft

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Research Timeline

1980 2000 2010 2018

Automated Maneuvering Attack System (AMAS)

Automation Research

AFTI/F-16
Advanced Fighter Technology Integration

Automated Collision Avoidance

Ground

Air

Integrated

AFTI & ACAT/F-16
Automated Collision Avoidance Technology

Dedicated Safety Work for Fighters

Ground Collision Avoidance

SmallUAS

GA

Quad-Rotor

Transition

Platform Diversity

SUAV/iGCAS/SR22
Improved Collision Avoidance System

Resilient Autonomy

1. **We began our work by developing an automatic ground collision avoidance system (GCAS) for fighters**
    - Completed research in 2011
    - Fielded in the USAF F-16 fleet 2014-15 / Fielded in the F-35 fleet late-2019
    - Credited with 9 life saves in the field to date

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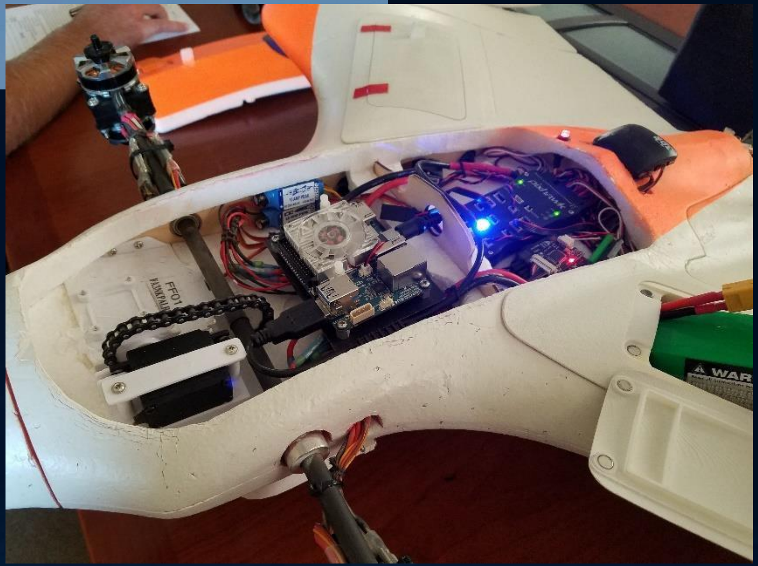
3. **Expanded towards Greater Autonomy on sUAV under NASA's UTM & SASO**
   - 2015 through 2017

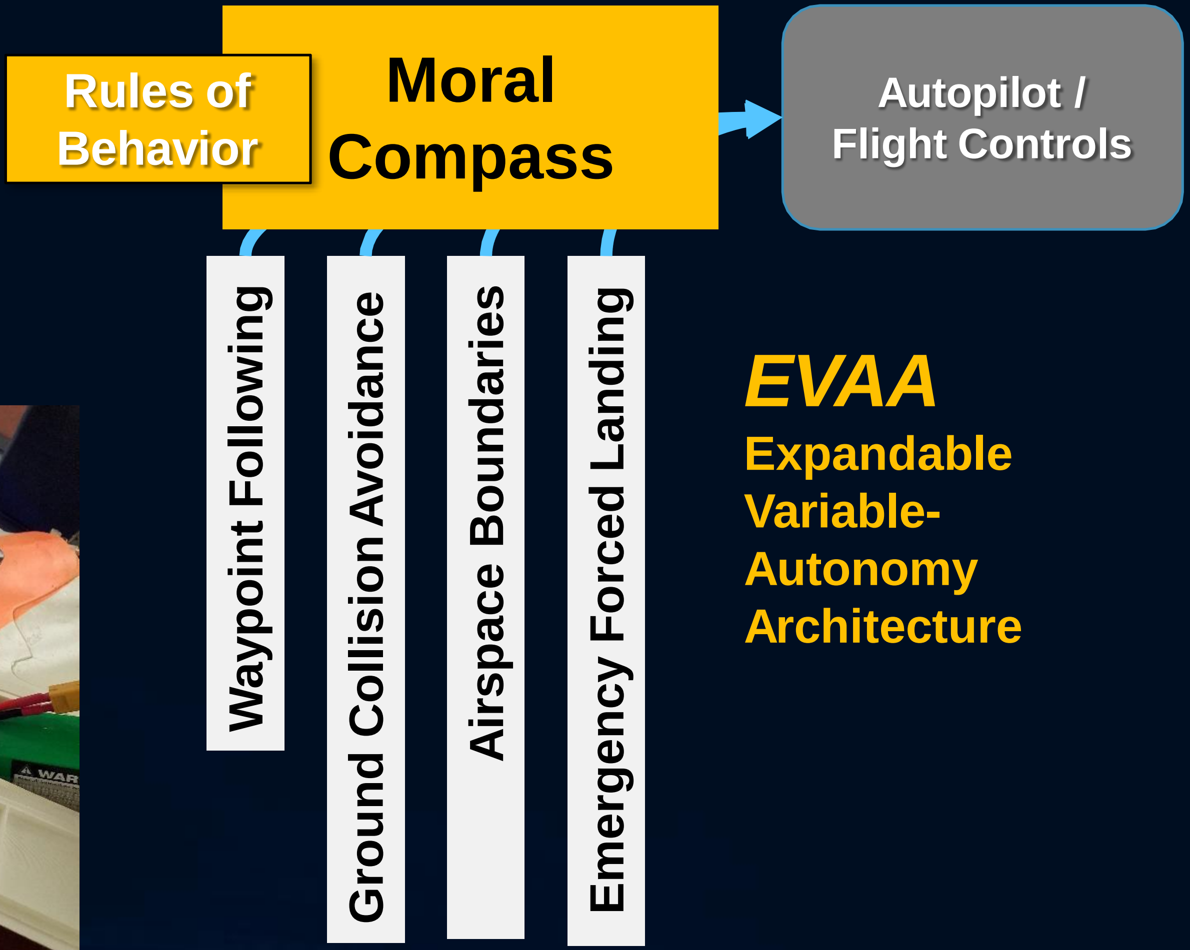





1. .

Broadening the Scope of Automatic Safety





EVAA

Expandable Variable-Autonomy Architecture

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   - Waypoint Following, GCAS, GeoFence, Forced Landing System (Sully/Hudson River)
     - How to coordinate command/control of the vehicle: a multi-monitor run-time assurance architecture
     - First phase of expandable variable-autonomy architecture (EVAA)
     - Unique part of this research: **The Moral Compass** & **Rules of Behavior**
       - When Safety should take priority over the mission & when protecting human life should take priority over vehicle safety

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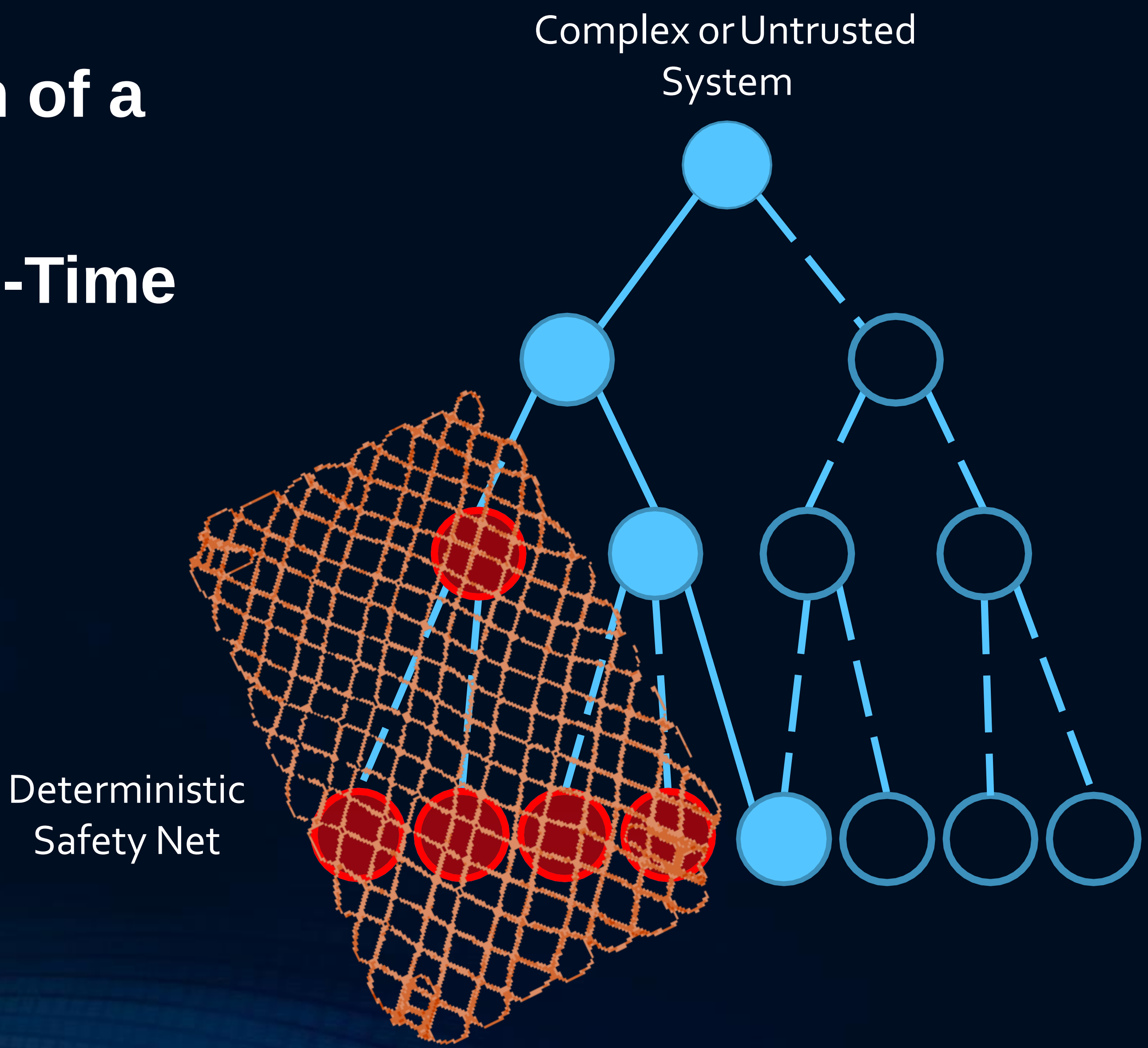
4. **The FAA Heard of this work: "Eureka, You have found the golden ring for certifying autonomy"**
   - ASTM working group was established to capture EVAA concept
   - Industry Standard was published October 2017 ***https://www.astm.org/Standards/F3269.htm***

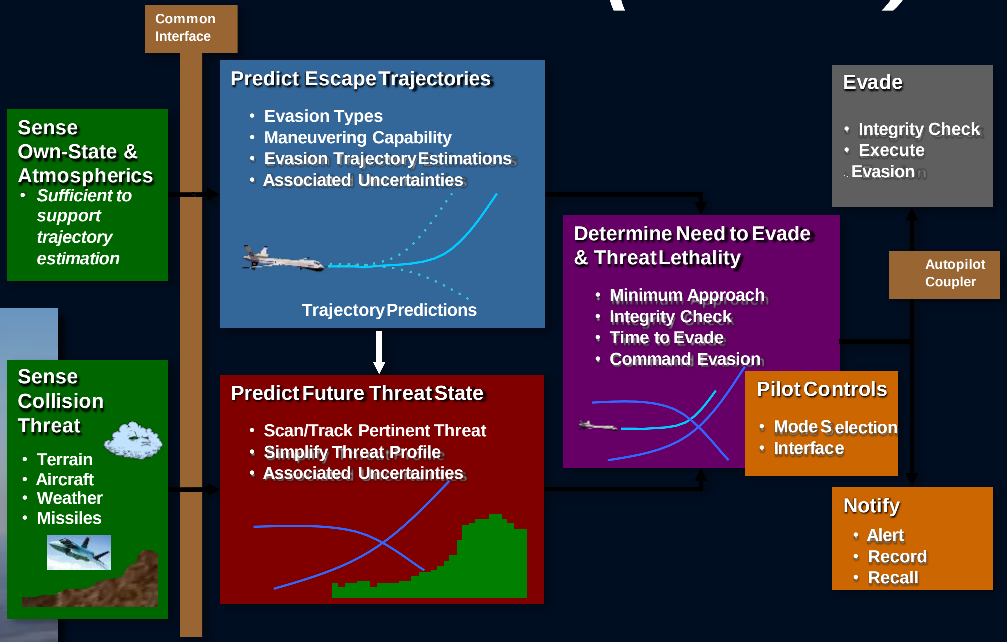
ASTM International

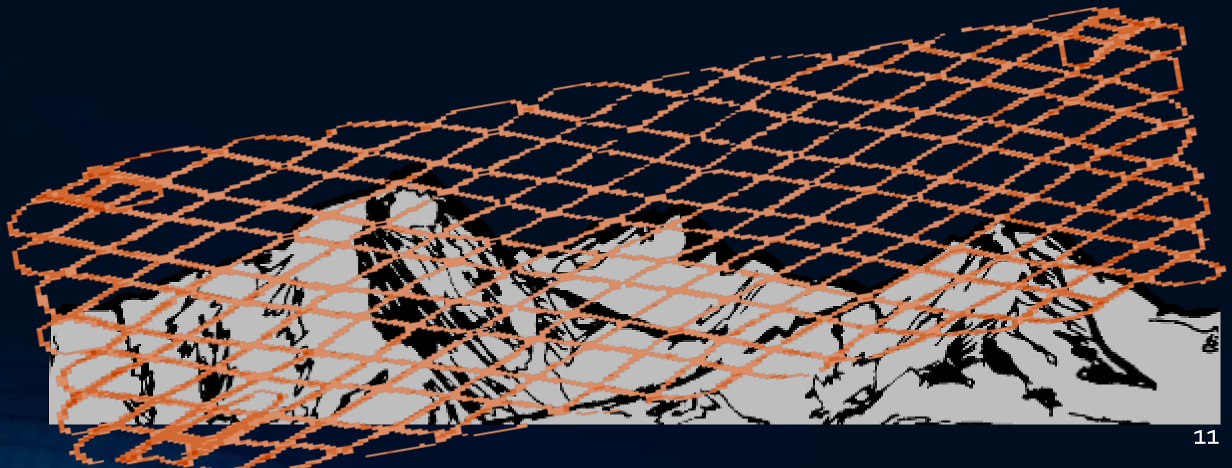
The Challenge of Autonomy

- **Verification & Certification of a Complex System**
- **A Possible Solution – Run-Time Assurance (RTA)**



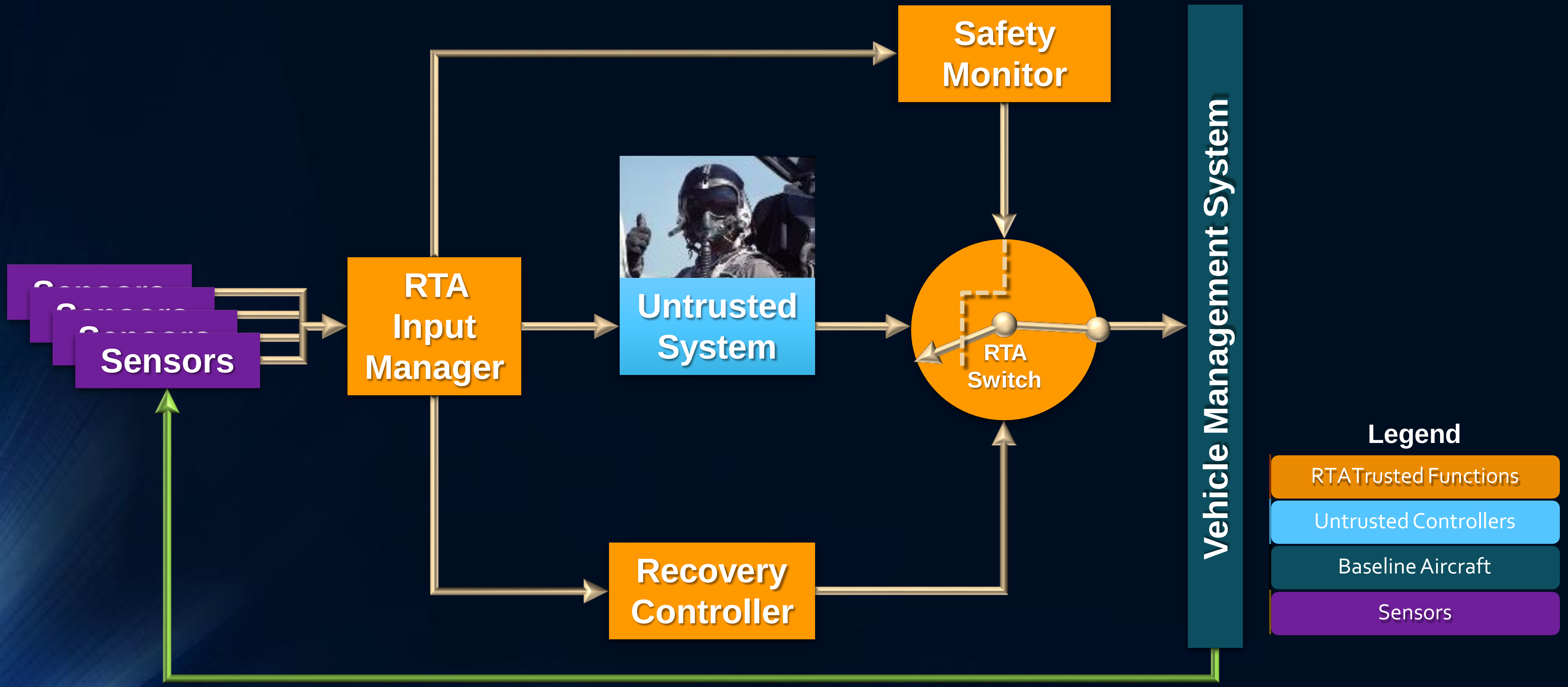
Ground Collision Avoidance System (GCAS)



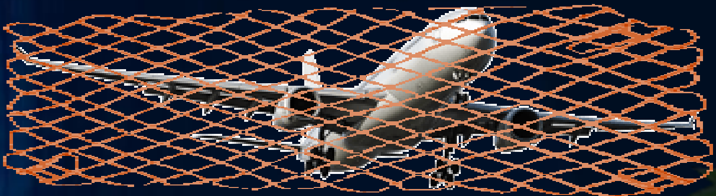
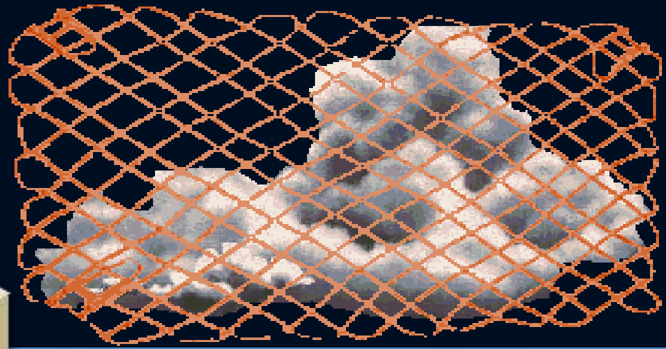
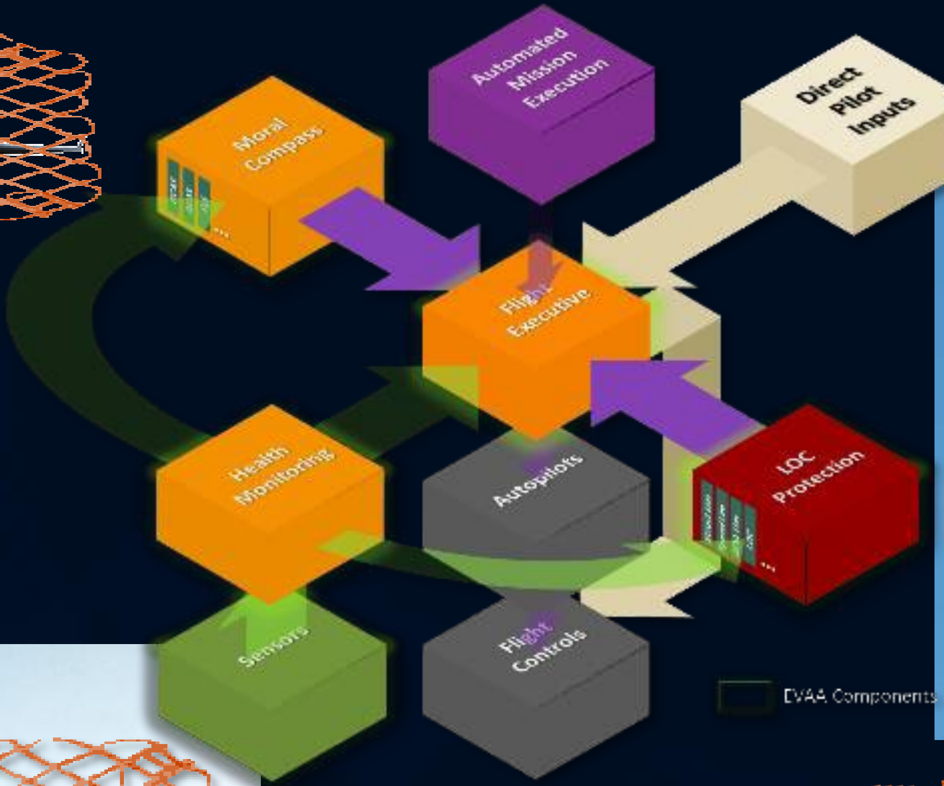


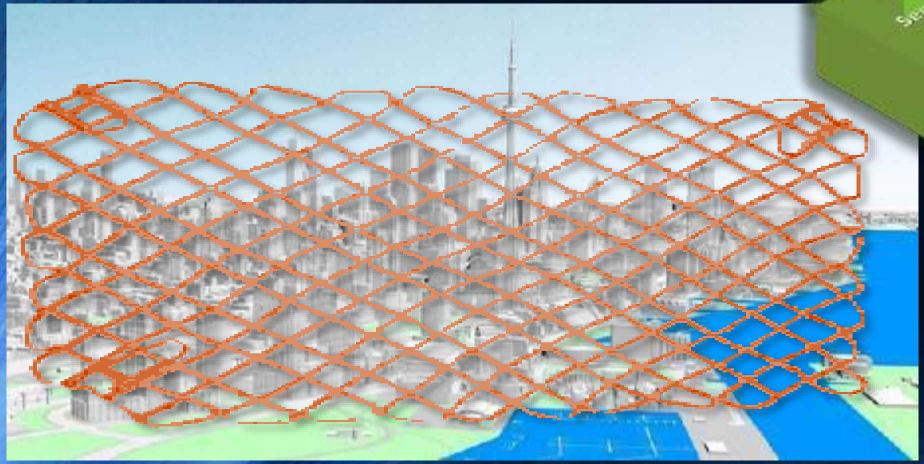
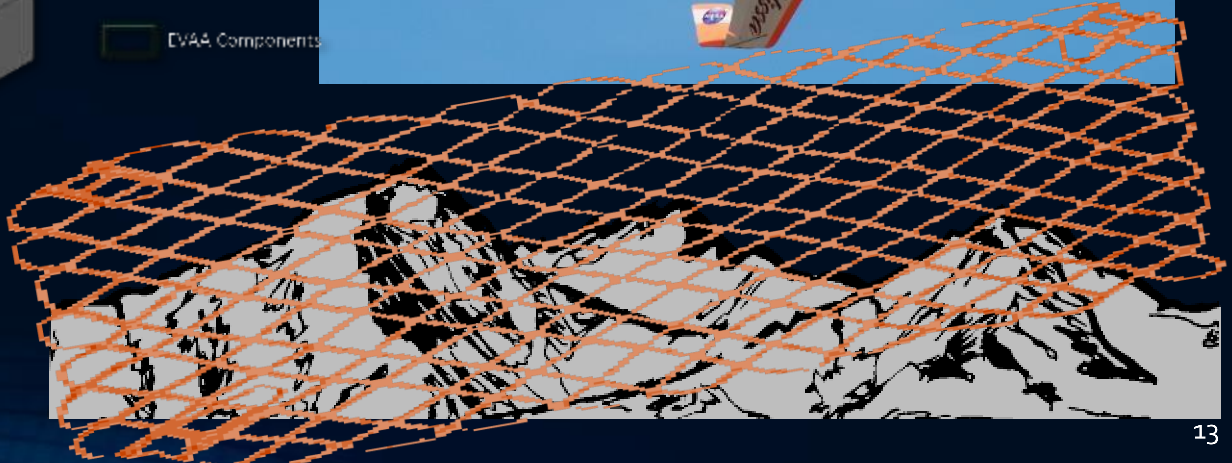
Traditional RTA Framework

https://www.astm.org/Standards/F3269.htm



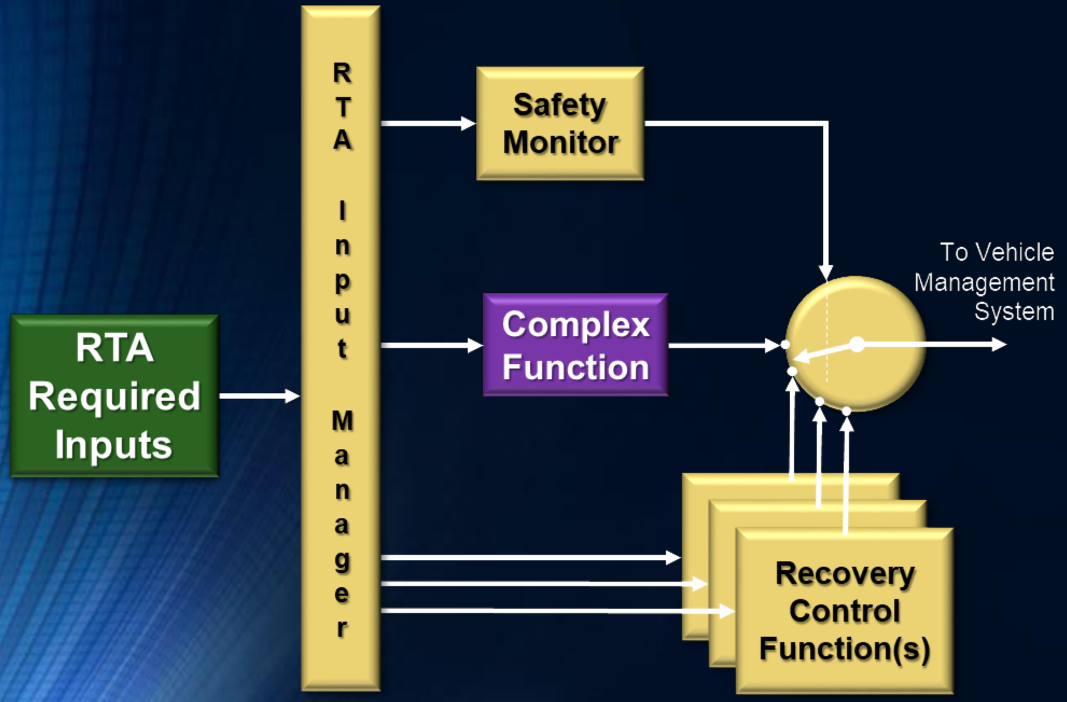
EVAA
Expandable Variable-Autonomy Architecture

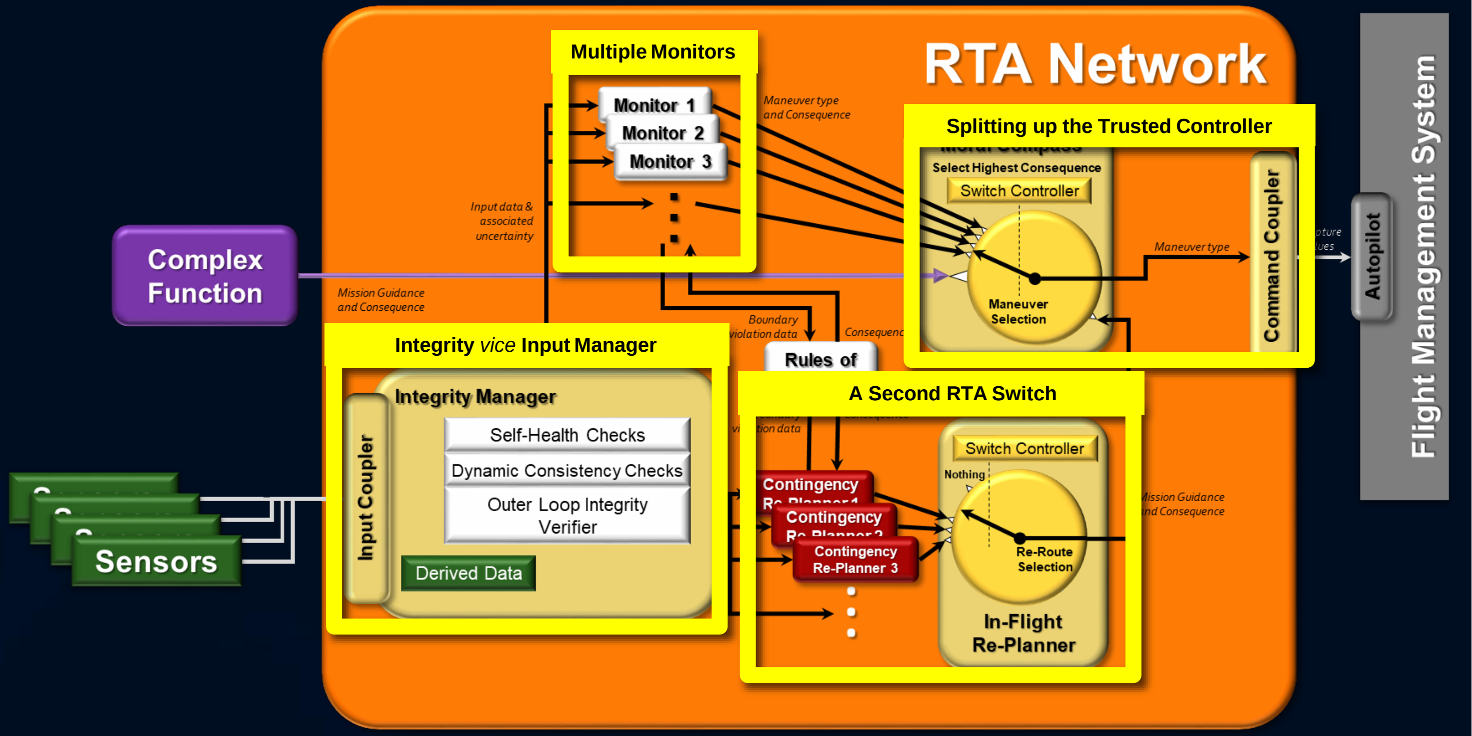




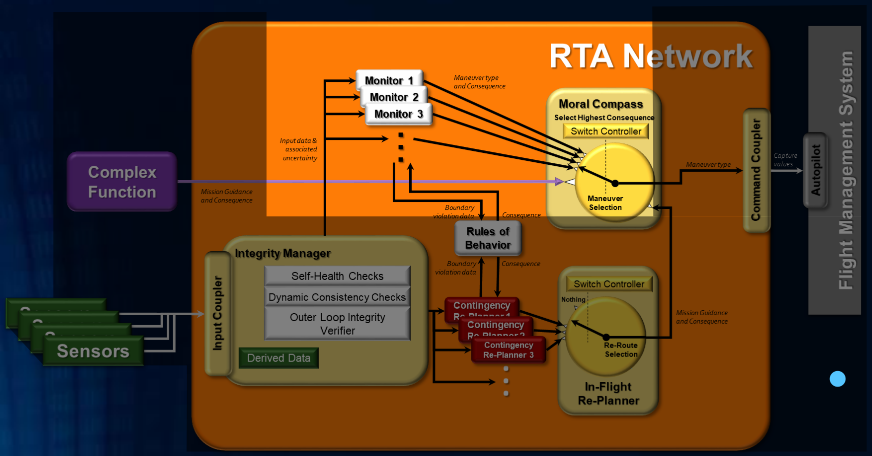
Leveraging the ASTM Standard

ASTM F3269-17
Published Illustration



Leveraged Implementation
Resilient Autonomy

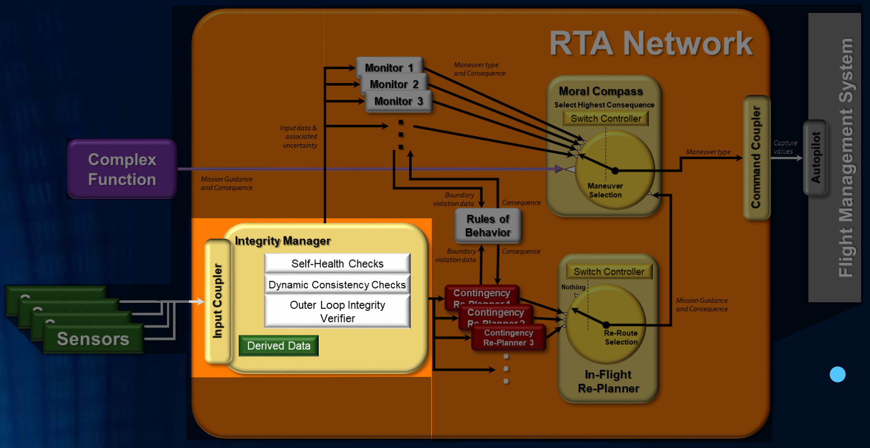




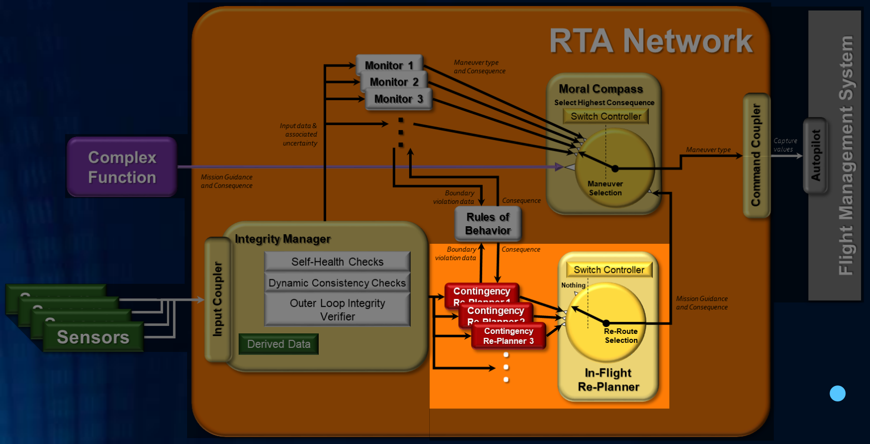
Multiple Monitors

- ***Understanding the different aircraft safety concerns and their connection to piloting tasks.***
- ***Decomposition of piloting tasks with emphasis on safety and/or ops?***
- ***Functional partitioning vs. single "mother of all" monitor (Why it makes sense to functionally partition)***
  - *Robustness of multiple simple systems vs. a single complex system*
  - *Ease of V&V*
- ***The need for a multi-position RTA switch***
- ***The need for consequence & therefore rules of behavior***

Integrity Manager



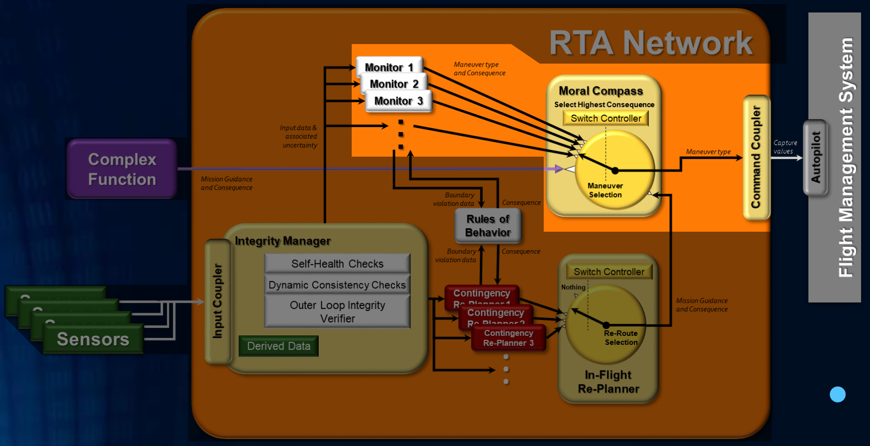
- ***Integrity vs redundancy***
- ***Integrity Monitors***
  - *Self-Health*
  - *Derived Inputs*
  - *Dynamic ConsistencyChecks*
  - *Outer-Loop Integrity Verification*



A Second RTA Switch

- *Addressing what should be done when integrity degrades*
- *Allowing the safety monitors to still work under emergency conditions*
- *Certitude differences with emergency systems*

Splitting up the Trusted Controller



- *Leveraging a pre-existing autopilot*
- *Monitors requesting a maneuver*
- *A command coupler translating a maneuver request*

Resilient Autonomy

Technology & Airworthiness Development & Transition

Performance Based Certification

F-16 Auto GCAS & ACAS

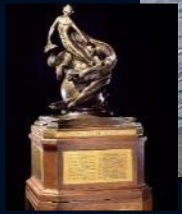
AvSP

ASTM
International

1st Industry Standard

UTM & SASO

Resilient Autonomy



2018 Collier

Autonomy Safety Standards

NASA

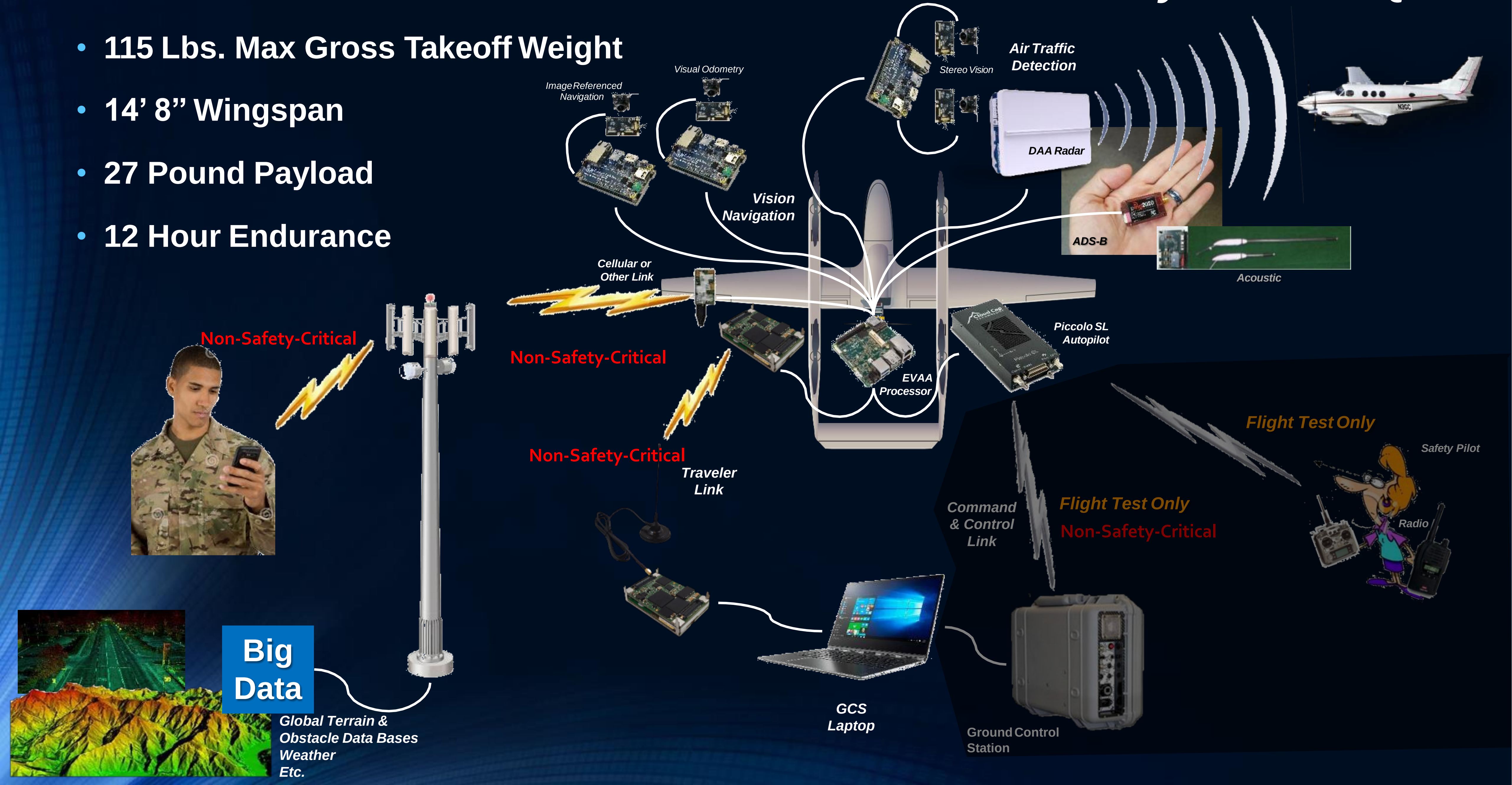
Industry

DoD

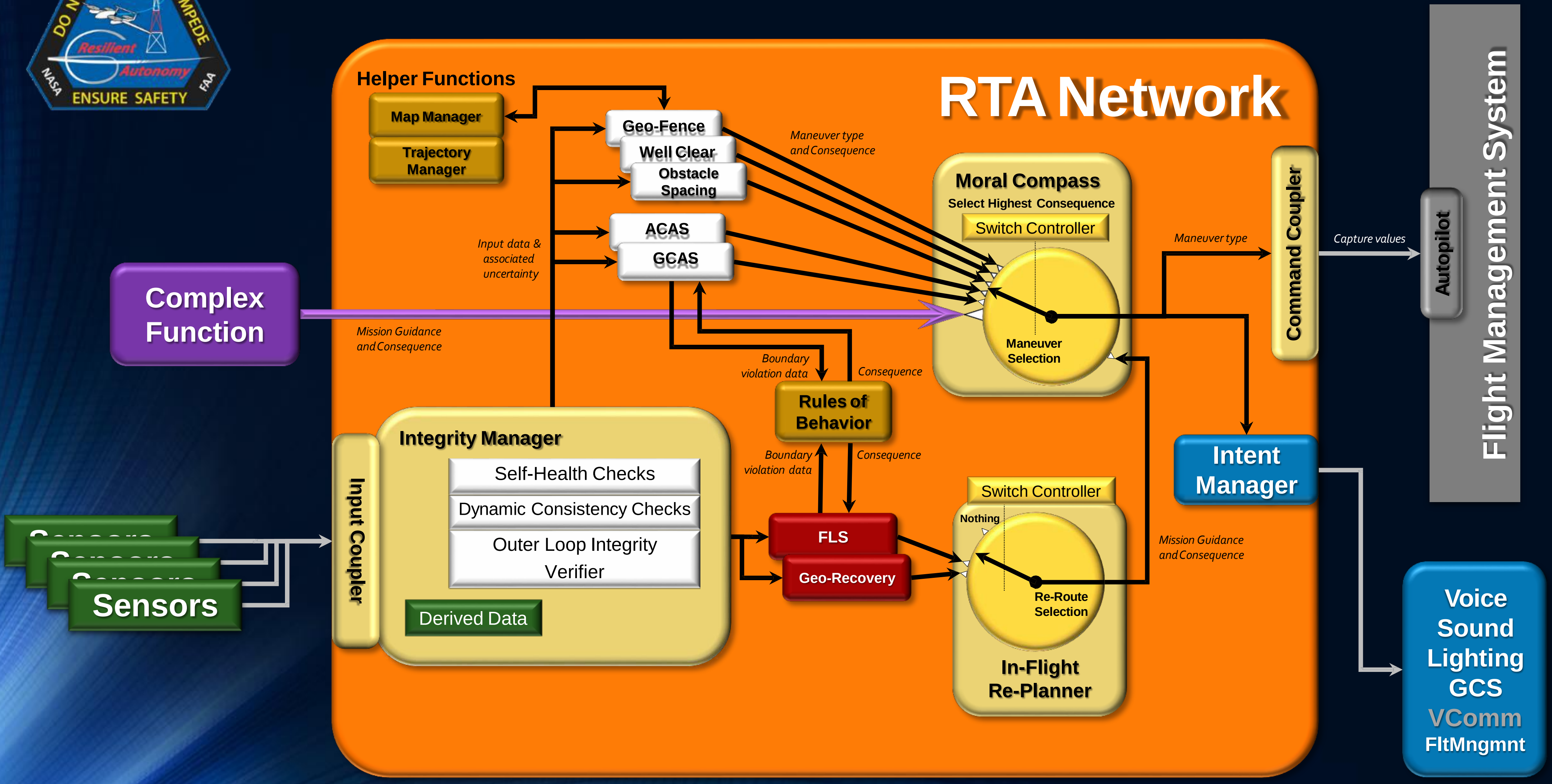
Reference Implementation Development

Resilient Autonomy EVAA/HQ-90

- 115 Lbs. Max Gross Takeoff Weight
- 14' 8" Wingspan
- 27 Pound Payload
- 12 Hour Endurance



RTA Network Architecture



Questions