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Unmanned Aircraft Systems Research and Innovation Challenges

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AESS IEEE Aerospace & Electronic Systems Society

AESS Distinguished Lecture – Delivered Online, 18th June 2024

Tutorial Outline

- Introduction
- Unmanned Aircraft Systems (UAS)
- UAS Avionics Research and Development
- UAS Cybersecurity Challenges
- UTM and AAM Research Efforts
- Q&A and Discussion

Introduction

About the Avionics Systems Panel

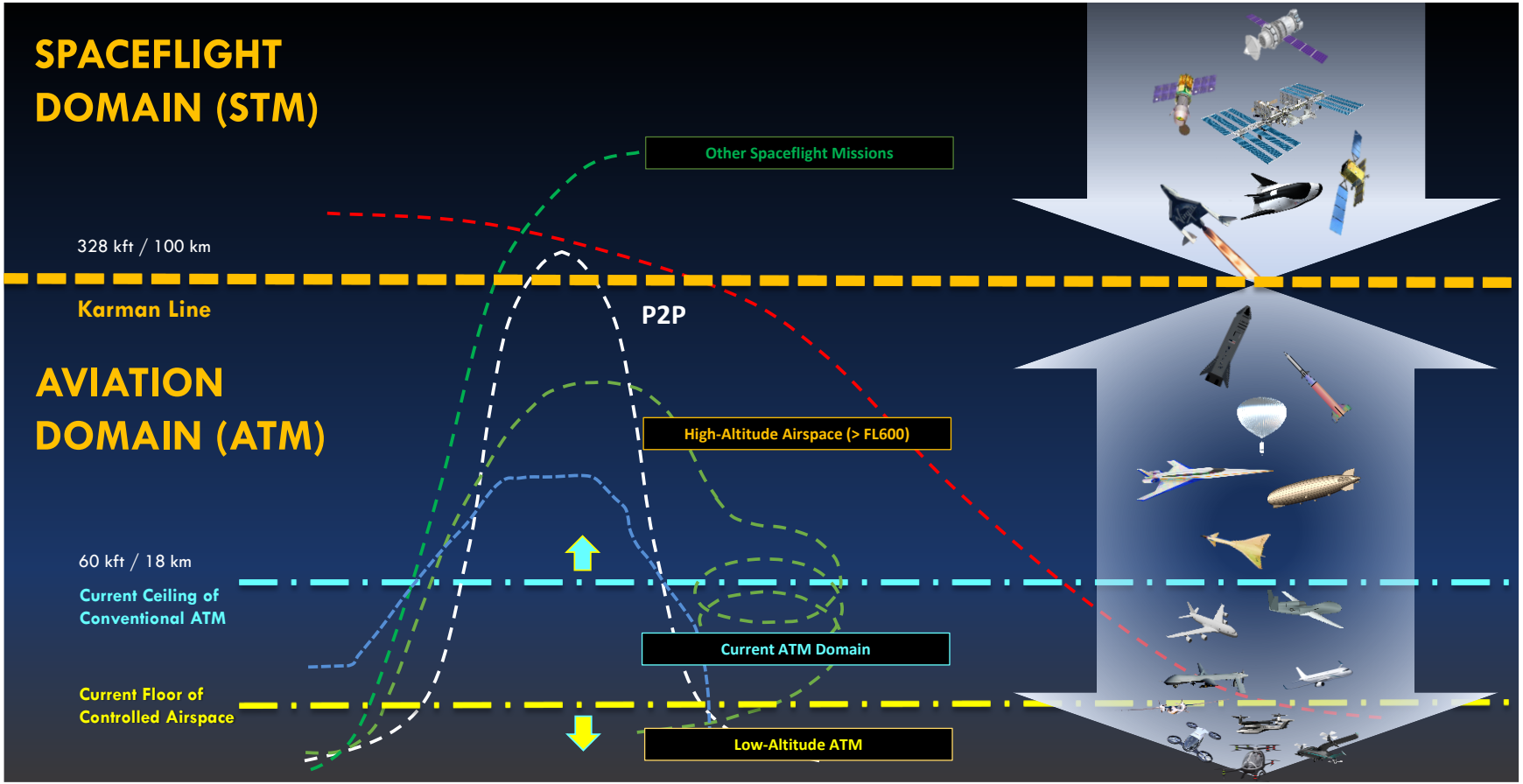
The Avionics Systems Panel (ASP) is composed of IEEE Associate or higher level members who are representatives of industry, government laboratories, educational institutions and professional societies, and who are active in the domain of Avionics. Its main objectives are:

- Promote and support collaborative research initiatives in the domain of Avionics
- Develop and disseminate high-quality IEEE publications in the domain of Avionics
- Promote and support educational activities in the domain of Avionics
- Sustain and oversee the programs of the IEEE/AIAA Digital Avionics Systems Conference (DASC) and the Integrated CNS Conference; and contribute to other conferences and dissemination initiatives
- Manage the nomination and selection of candidates for IEEE Awards in the domain of Avionics
- Encourage submission of nominations for IEEE Fellows and Senior Members in the domain of Avionics
- Recommend and support new IEEE avionics standards or revisions of existing standards

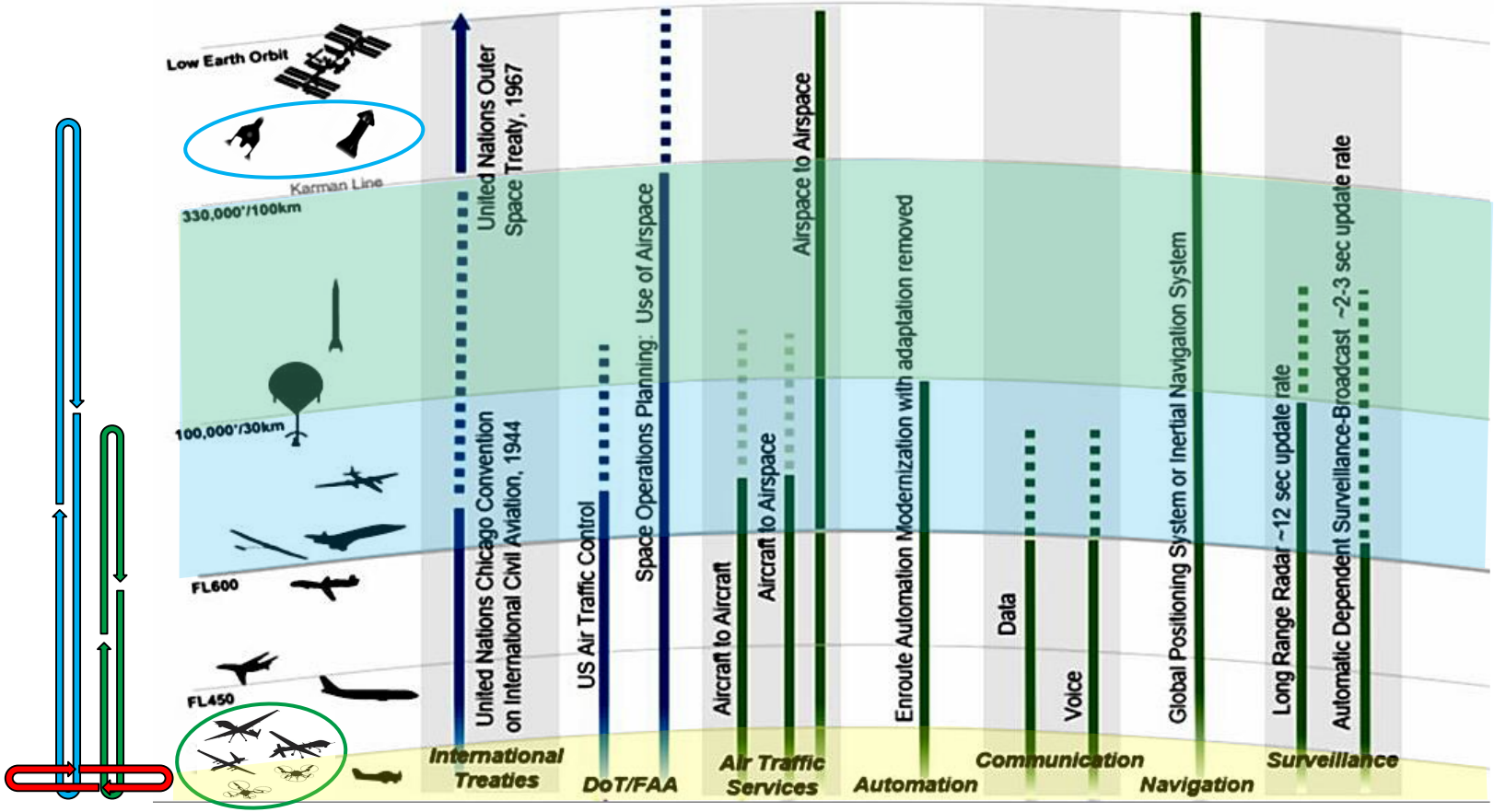
ASP Research and Innovation Focus

- The ASP is collaborating with ICAO, IFATCA, EASA, EUROCAE, NASA, JARUS, NextGen and SESAR initiatives to promote avionics research/innovation, education and the evolution of certification standards. Increasing focus on AI, UAS Traffic Management and Advanced Air Mobility (Regional and Urban Air Mobility)
- Current activities focus on:
  - ATM and UTM/AAM Automation
  - Autonomous Navigation and Guidance Systems
  - Advances in Human-Machine Systems
  - Automation and Trusted Autonomy
  - Multiple Simultaneous Operations
  - Avionics CPS and Cyber-security

Evolving Flight Domains



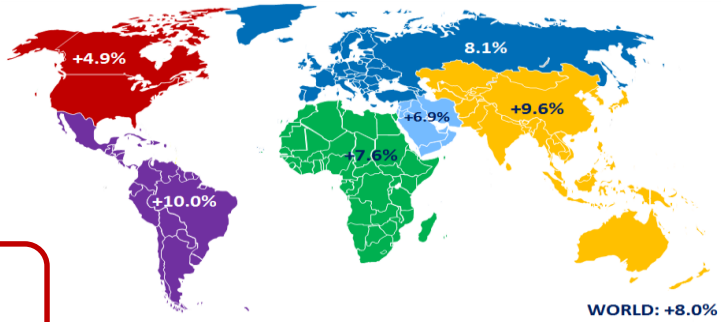
Evolving Airspace and Avionics Systems

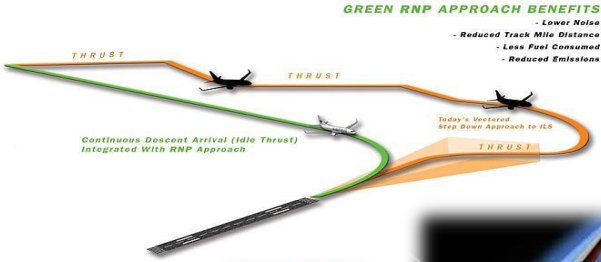


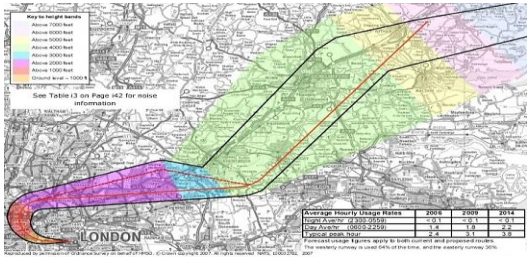
Current Industry Challenges

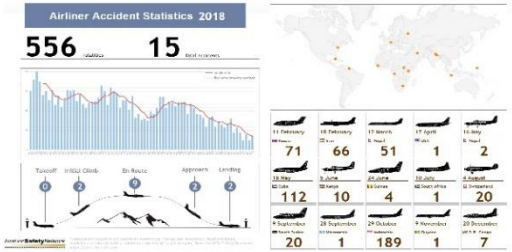
- **Enhancing <u>Safety, Efficiency and Sustainability</u> of aviation and space transport operations to support the anticipated growth of the sector**

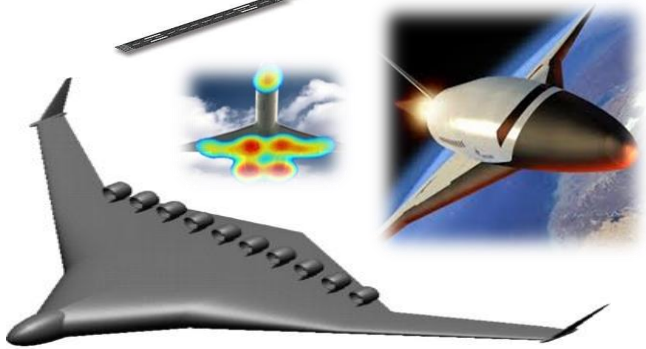
- **Research and Innovation Areas**
  - Next Generation ATM Communications, Navigation, Surveillance (CNS) & Avionics (A) Systems (CNS+A)
  - UAS access to all classes of airspace (trusted autonomy)
  - Development and rapid uptake of low-emission technologies (gaseous and noise emissions)
  - Improved efficiency and capacity of airports and spaceports (digitalisation/multimodal)
  - Solutions for enhanced safety and security



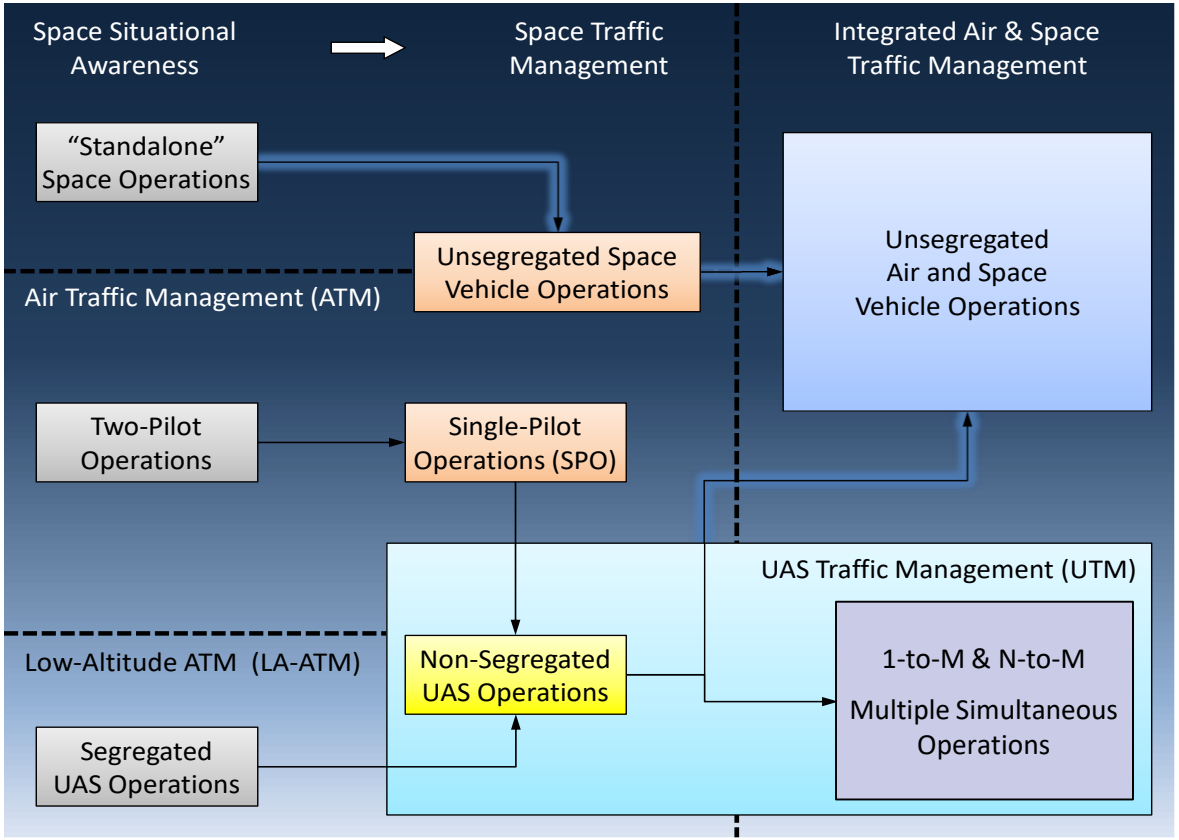








Avionics Systems Evolution



IEEE Aerospace & Electronic Systems Society

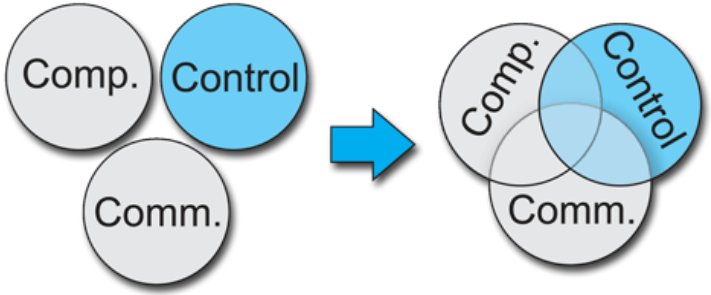
R. Sabatini, A. Roy, E. Blasch, K. A. Kramer, G. Fasano, I. Majid, O. G. Crespillo, D. A. Brown and R. Ogan, "Avionics Systems Panel Research and Innovation Perspectives." IEEE Aerospace and Electronic Systems Magazine, Vol. 35, Issue 12, pp. 58-72, December 2020.

G. Fasano, O. G. Crespillo, R. Sabatini, A. Roy, and R. Ogan, "From the Editors of the Special Issue on Urban Air Mobility and UAS Airspace Integration: Vision, Challenges, and Enabling Avionics Technologies." IEEE Aerospace and Electronic Systems Magazine, Vol. 38, No. 5, pp. 4-5, May 2023.

Unmanned Aircraft Systems

UAS and Cyber-Physical Systems

- **UAS are examples of Cyber-Physical Systems (CPS). CPS are engineered through the seamless integration of digital and physical components, with the possibility of including human interactions**
- This requires **three fundamental functions** to be present: **Control, Computation and Communication (C^3)**
- Practical CPS typically combine sensor networks and embedded computing to monitor and control physical processes, with feedback loops that allow physical processes to affect computations and vice-versa



Avionics CPS

- **The Avionics community focuses on two special categories of CPS:**
  - **Autonomous Cyber-Physical (ACP) systems**
  - **Cyber-Physical-Human (CPH) systems**
- **ACP systems operate without the need for human intervention or control. For ACP systems to work, formal reasoning is required** as these systems are commonly used to accomplish mission/safety-critical tasks, and any deviation from the intended behavior may have significant implications on human health, well-being, economy, etc.
- A sub-class is that of Semi-Autonomous Cyber-Physical (S-ACP) systems, which perform autonomous tasks in a specific set of pre-defined conditions but require a human operator otherwise

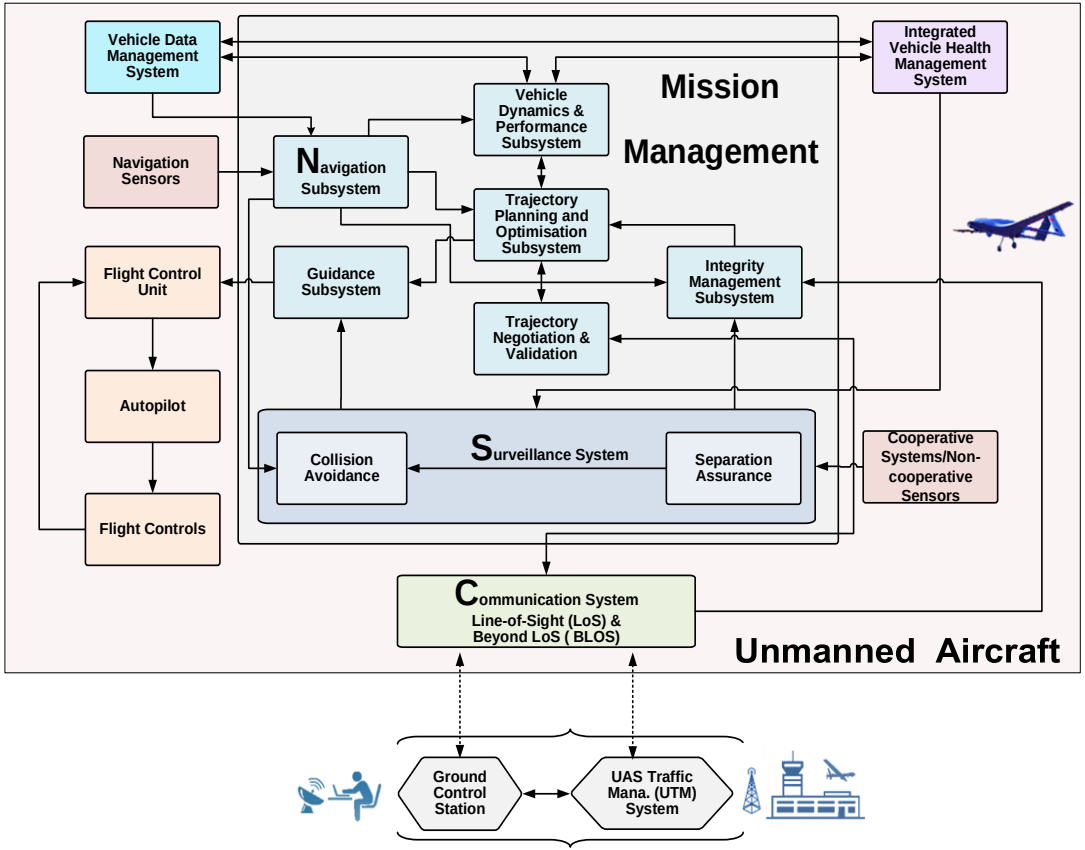
CPH Systems

- **A separate category is that of CPH systems. These are a particular class of CPS where the interaction between the dynamics of the system and the cyber elements of its operation can be influenced by the human operator and the interaction between these three elements is regulated to meet specific objectives**
- CPH systems consist of three main components: **physical elements** sensing and modelling the environment, the systems to be controlled and the human operators; **cyber elements** including the communication links and software; and **human operators** who supervise/monitor the operation of the system and can intervene if and when needed

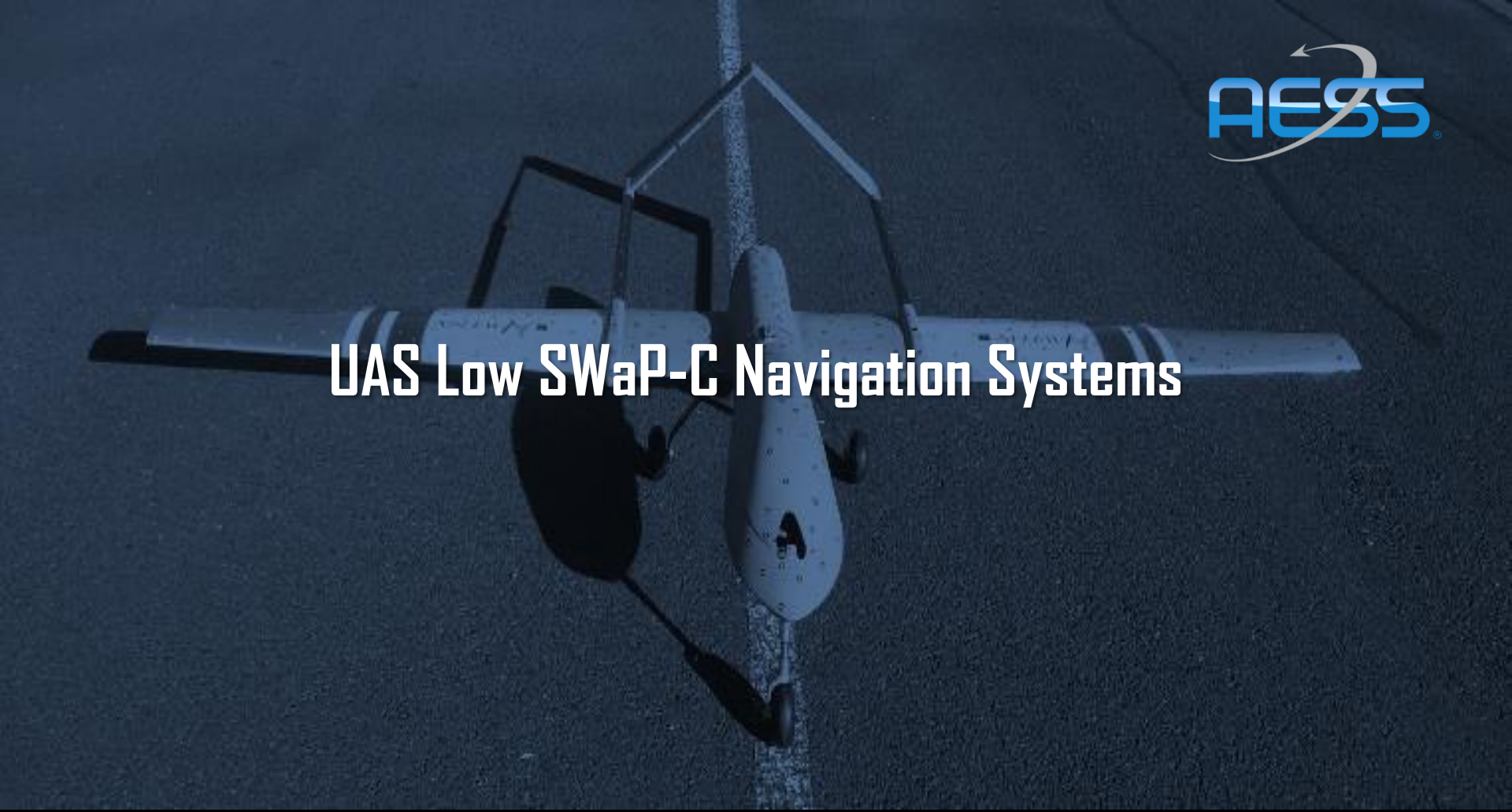
CPS for Trusted Autonomous Operations

- Current research aims at developing **robust and fault-tolerant ACP and CPH system architectures that ensure trusted autonomous operations with the given hardware constraints, despite the uncertainties in physical processes, the limited predictability of environmental conditions, the variability of mission requirements (especially in congested or contested scenarios), and the possibility of both cyber and human errors**
- A key point in these advanced CPS is the control of physical processes from the monitoring of variables and the use of computational intelligence to obtain a deep knowledge of the monitored environment, thus providing timely and more accurate decisions and actions

UAS Avionics Architecture



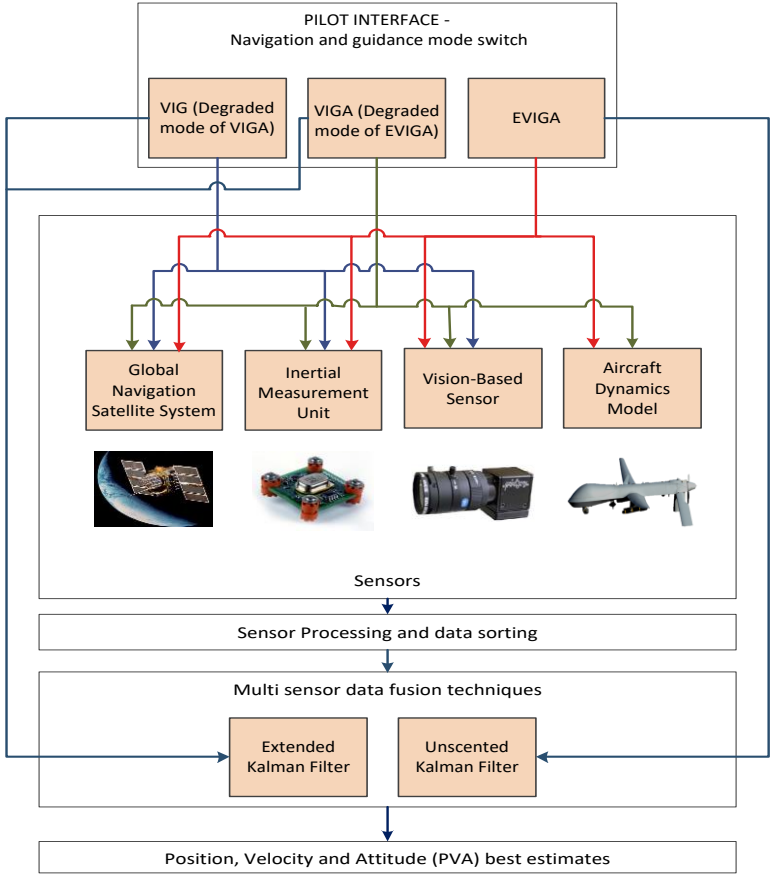
UAS Avionics R&D



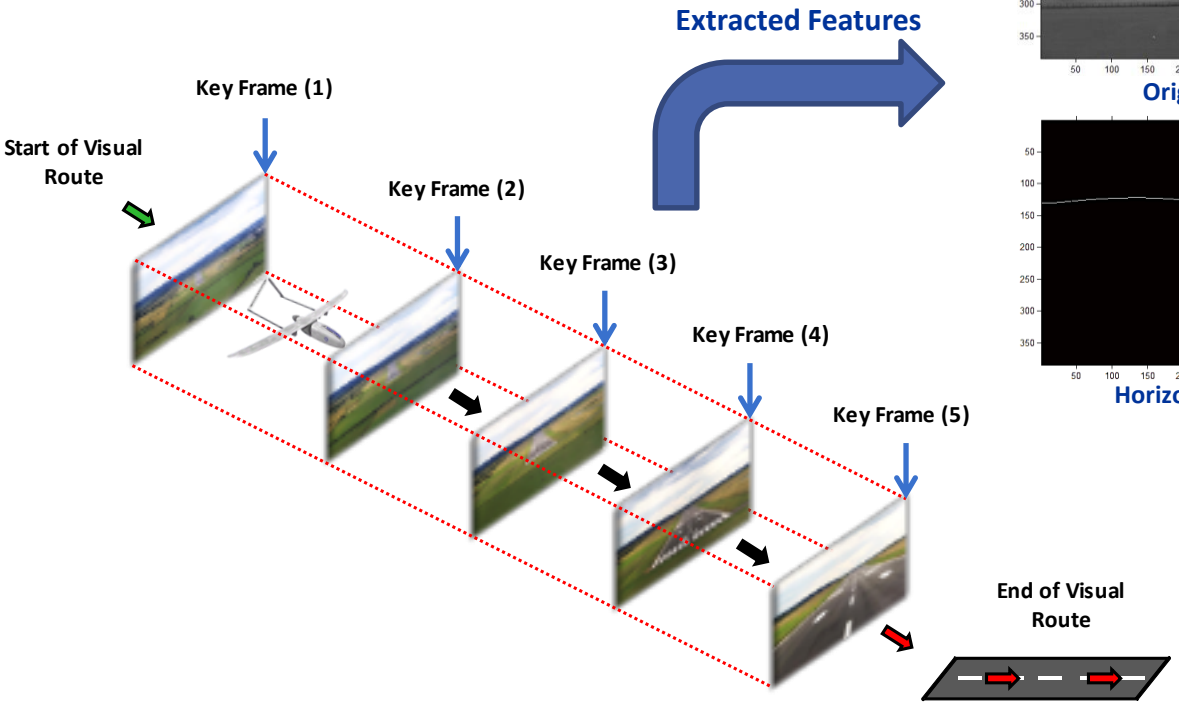
UAS Low SWaP-C Navigation Systems

Integration Architecture

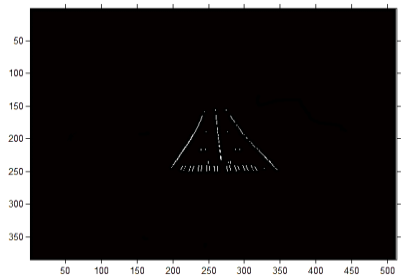
Data	Position	Velocity	Attitude Angles	Attitude Rates
IMU	✓	✓	✓	✓
GNSS	✓	✓		
ADM	✓	✓	✓	✓
VBS			✓	✓

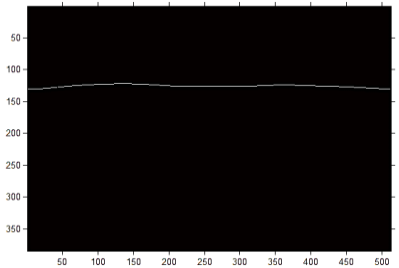


Vision-Based Navigation




Original Image


Runway Markings Detection


Horizon Detection

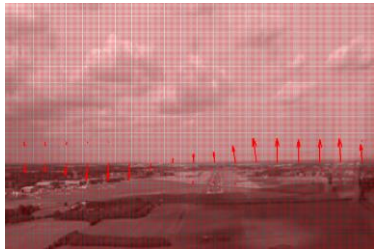
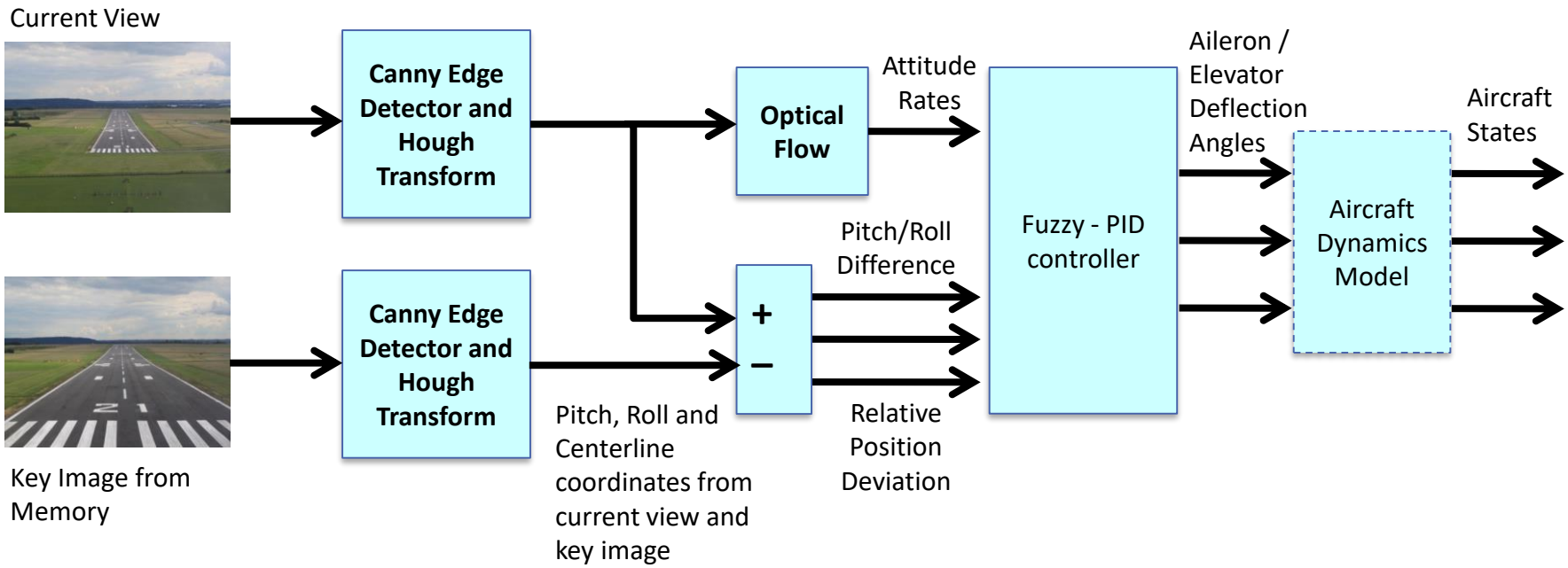
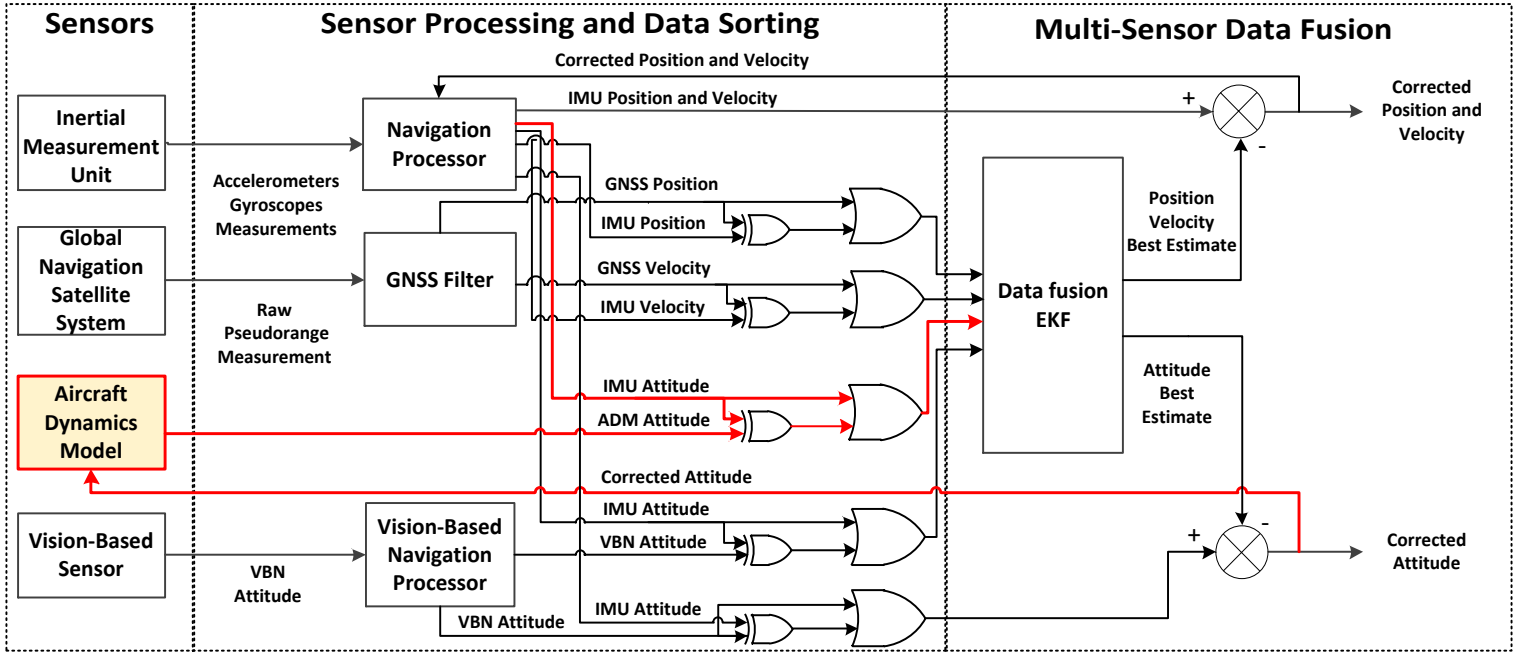

Optical Flow

Image Processing Module



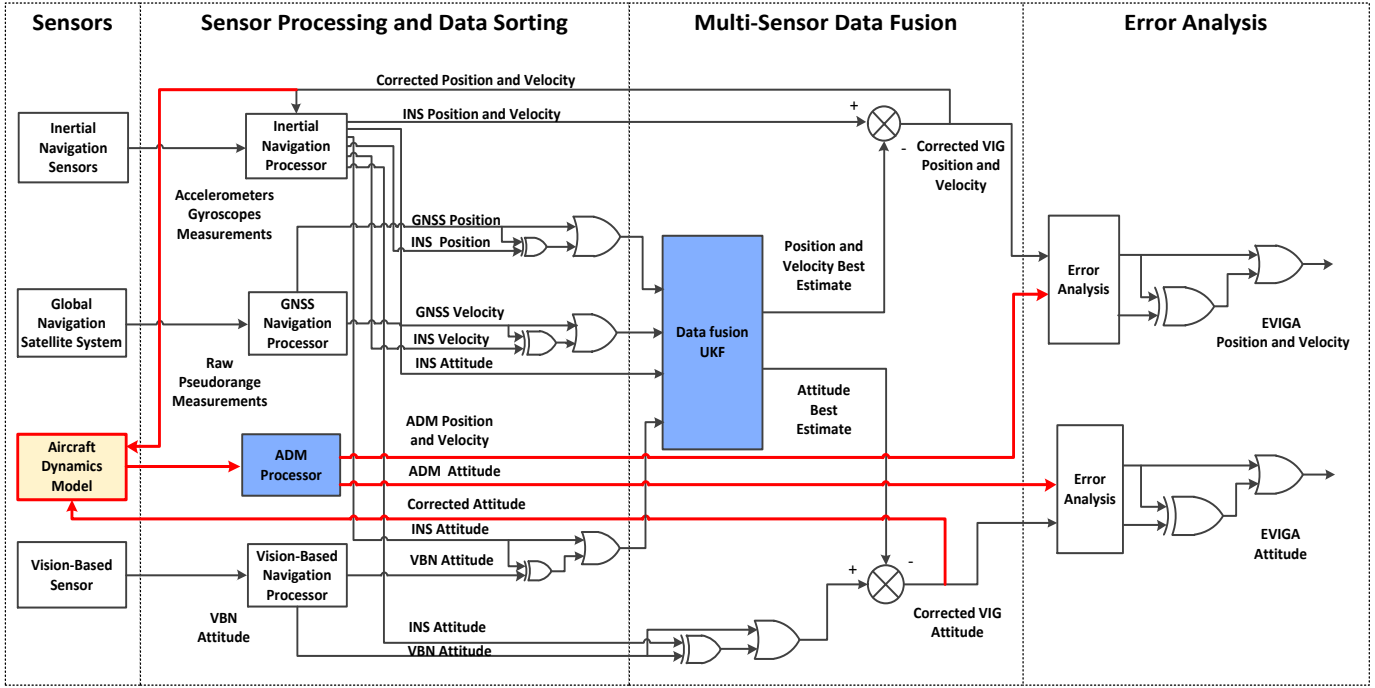
Integration Architectures

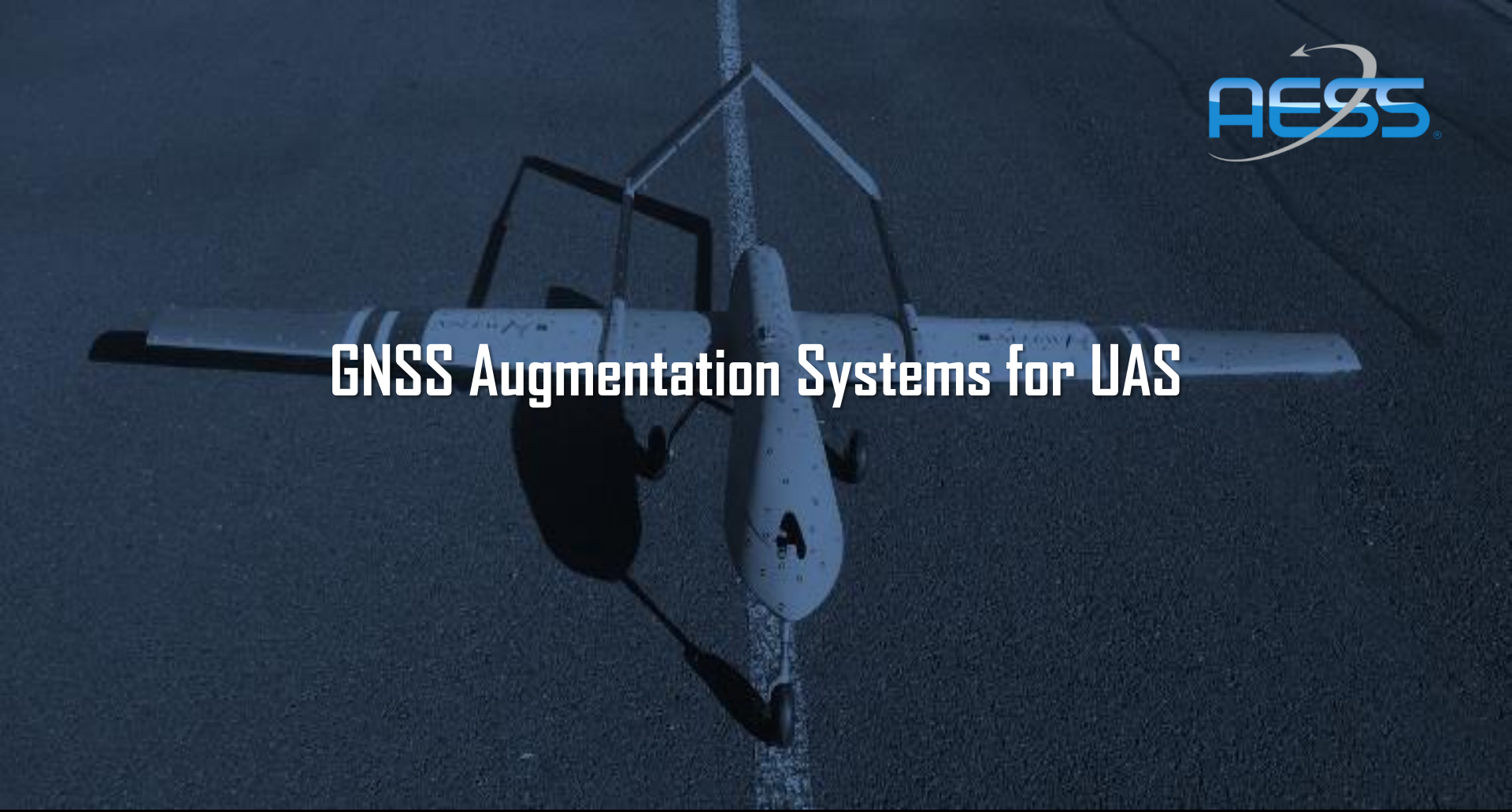
- VBN/INS/GNSS (VIG)
- VBN/INS/GNSS/ADM (VIGA)



Integration Architectures (2)

- Unscented Kalman Filter (UKF) based Configuration (UVIGA)





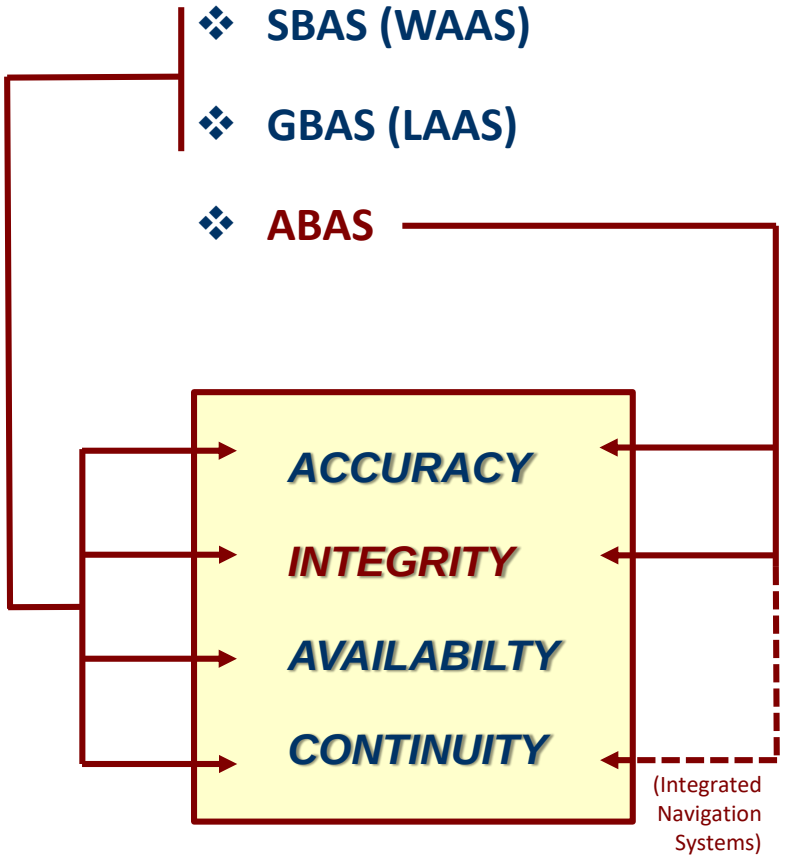
GNSS Augmentation Systems for UAS

GNSS Augmentation Benefits

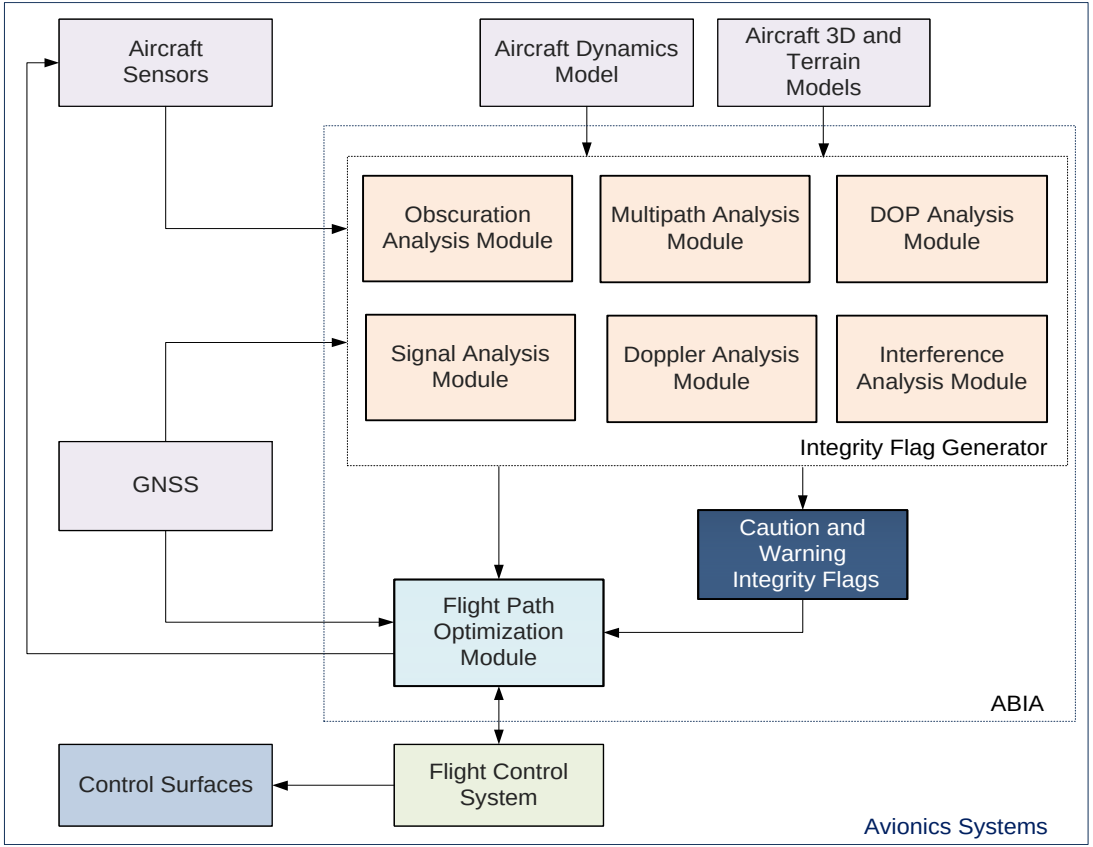
- **GNSS augmentation benefits in aviation** include:
  - Precision approach and landing autonomous ops
  - Ops in urban Environments
  - Interference and jamming resistance/avoidance
  - Reduced and simplified equipment on board aircraft
  - Predictive integrity for optimal AI/ML data fusion

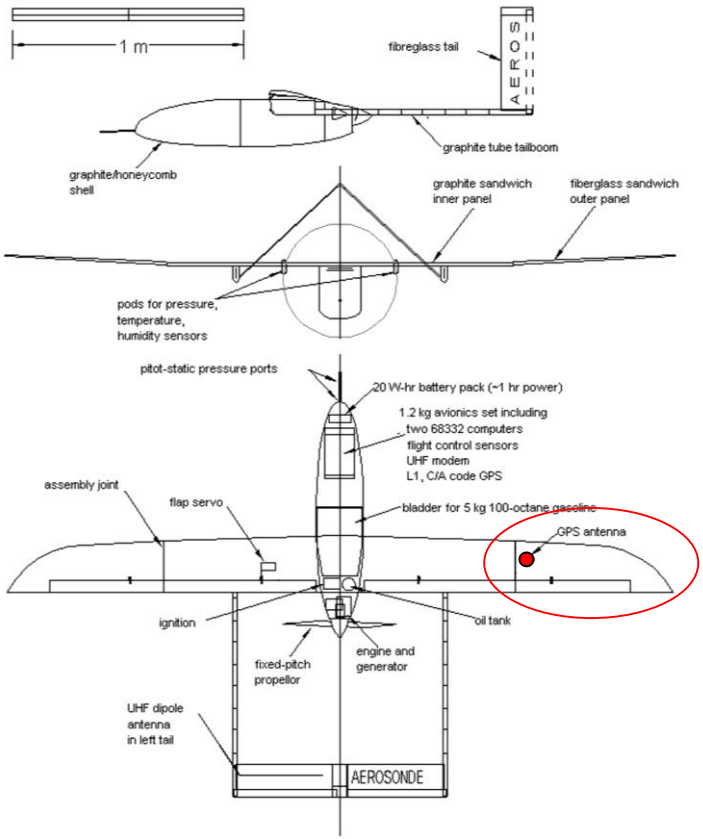
- In addition to SBAS and GBAS, GNSS augmentation may take the form of additional information being provided by **other avionics systems.** The additional avionics systems operate via separate principles than the GNSS and, therefore, are **not subject to the same sources of error or interference**

- A system such as this is referred to as an **Aircraft** (or Avionics) **Based Augmentation System (ABAS)**



ABIA Architecture





ABIA Integrity Flags

ALERTS

Caution Integrity Flag (CIF):

A ***predictive annunciation*** that the GNSS data delivered to the avionics system is going to exceed the Required Navigation Performance (RNP) thresholds specified for the current and planned flight operational tasks (GNSS alert status)

Warning Integrity Flag (WIF):

A ***reactive annunciation*** that the GNSS data delivered to the avionics system has exceeded the Required Navigation Performance (RNP) thresholds specified for the current flight operational task (GNSS fault status)

TTA

ABIA Time-to-Caution (TTC):

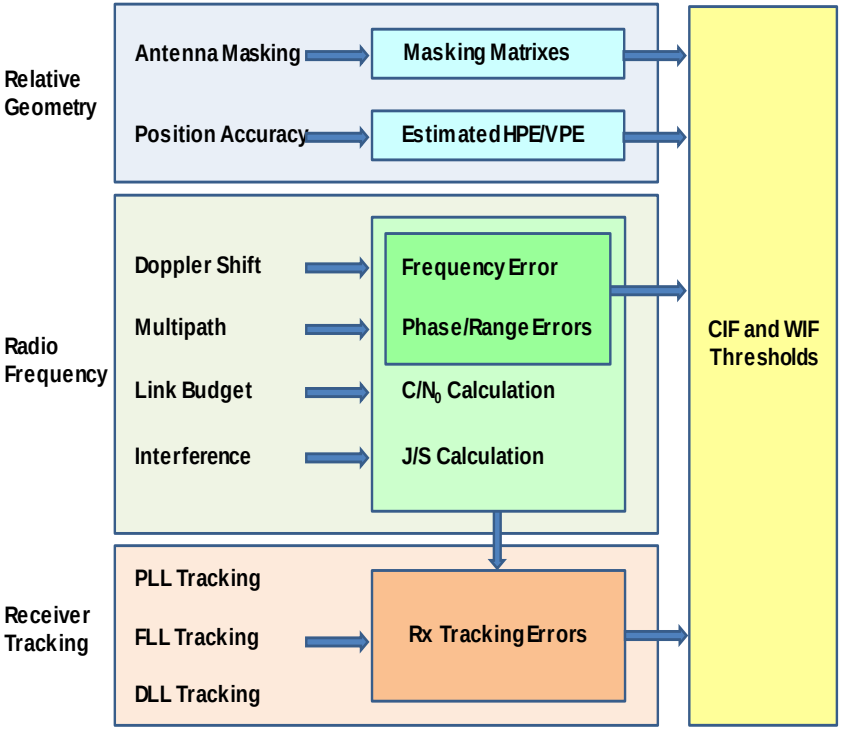
The **minimum time allowed** for the caution flag to be provided to the user before the onset of a GNSS fault resulting in an unsafe condition

ABIA Time-to-Warning (TTW):

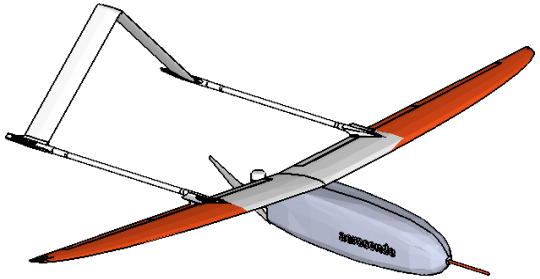
The **maximum time allowed** from the moment a GNSS fault resulting in an unsafe condition is detected to the moment that the ABIA system provides a warning flag to the user

GNSS Performance Threats

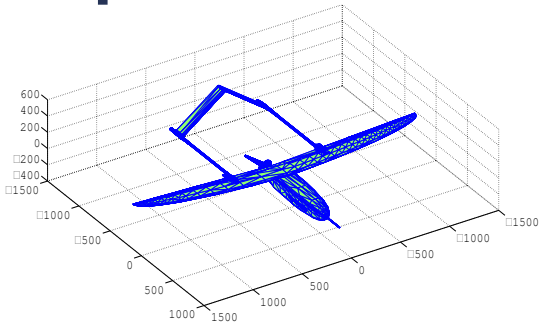
- **Causes of GNSS data degradation or loss:**
  - **Obscuration**
  - **Bad satellite geometry (DOP)**
  - **Fading (low C/N_0)**
  - **Doppler shift (signal tracking, acquisition time)**
  - **Multipath effect (C/N_0, range and phase errors)**
  - **Interference and Jamming**
- GNSS signal outages/degradations models are used in association with suitable integrity thresholds and guidance algorithms
- Using these models, the ABIA system is able to generate integrity caution (predictive) and warning (reactive) flags, as well as steering information to the pilot and electronic commands to the aircraft/UAV flight control system



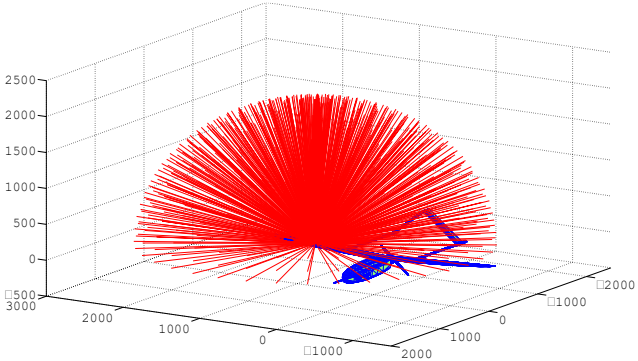
AEROSONDE Example

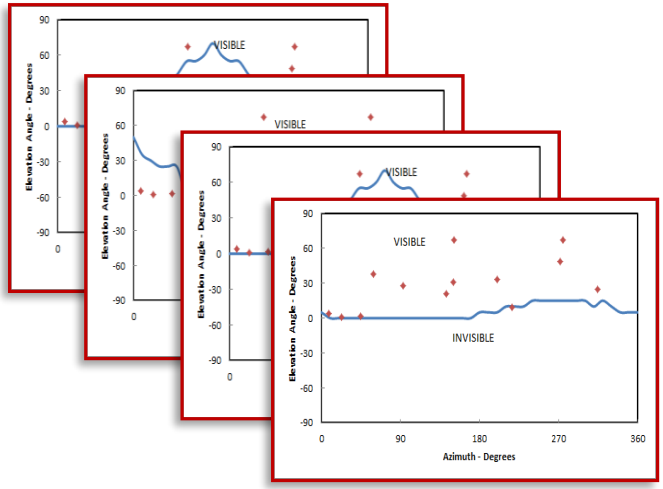


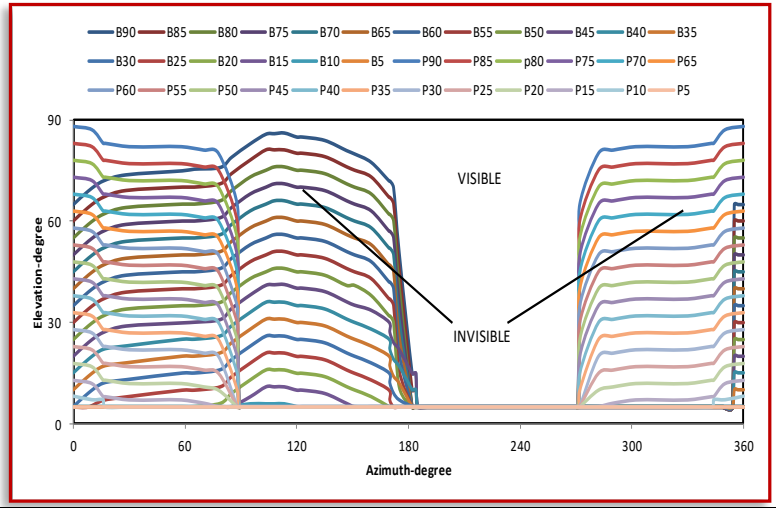
CAD Model



Stereo-Lithography (STL) Format





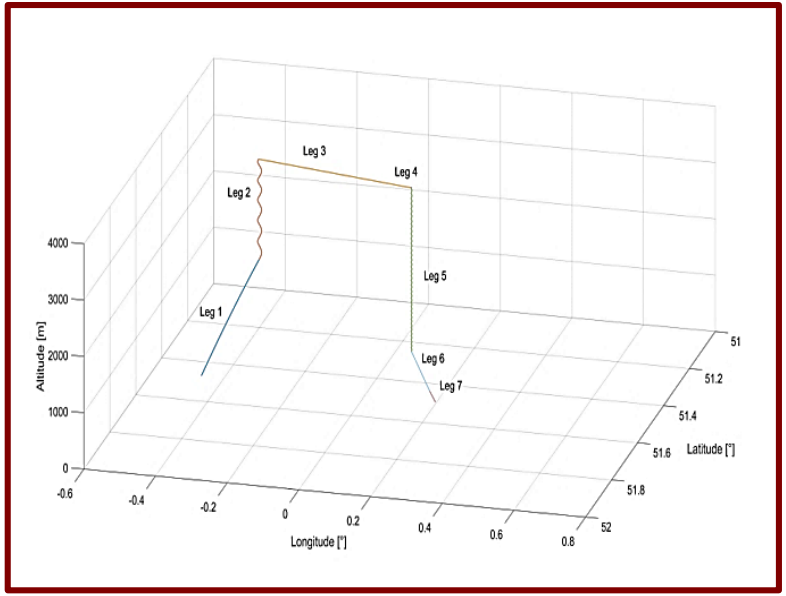


CIF/WIF Criteria

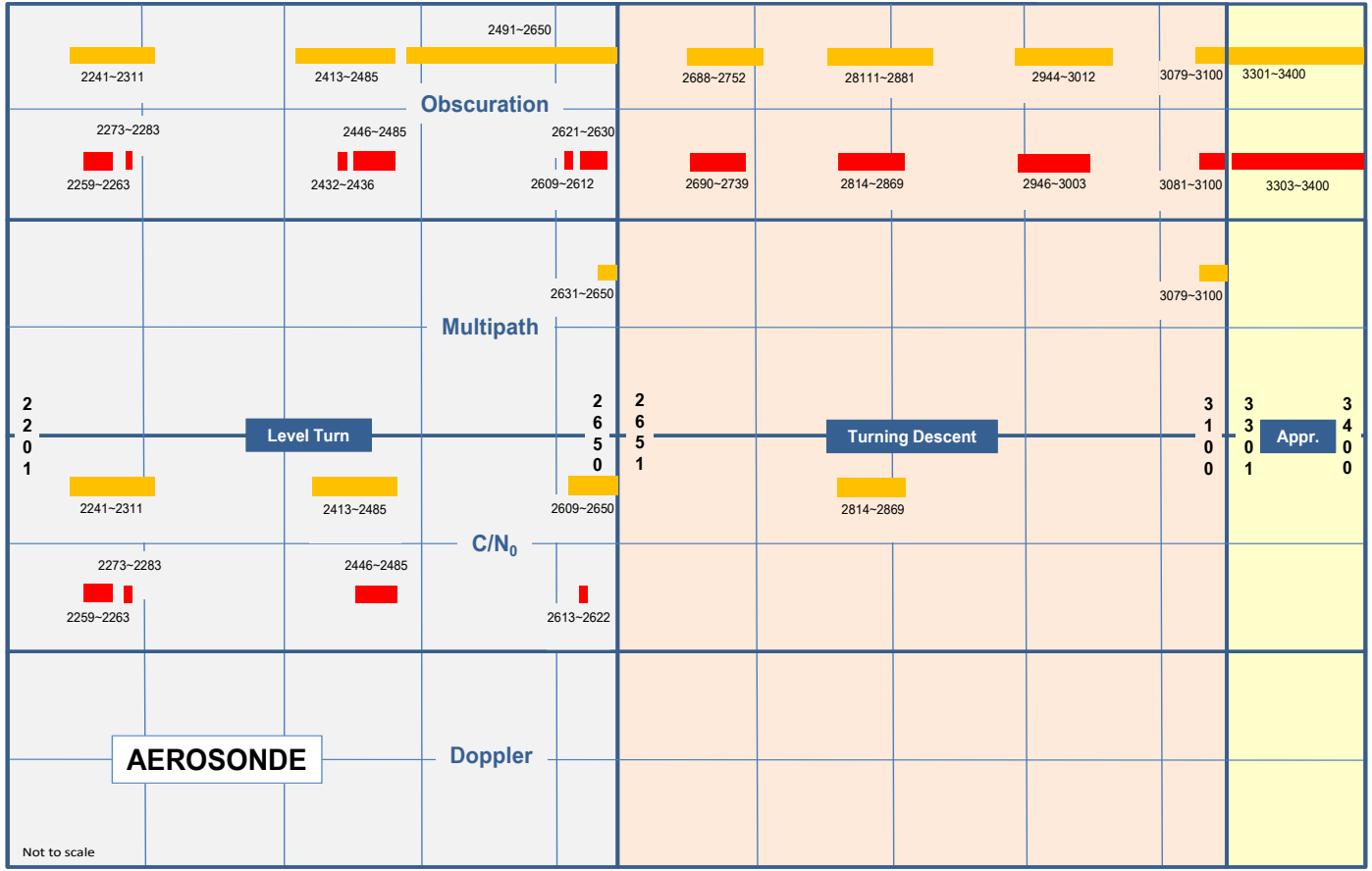
Integrity Event	Integrity Flags Criteria
Obscuration	***CIF*** – When the current A/C manoeuvre will lead to less the 4 satellite in view, the CIF is generated
	WIF – When less than 4 satellites are in view, the WIF is generated
Elevation	***CIF*** – When one (or more) satellite(s) elevation angle (antenna frame) is less than 10 degrees, the caution integrity flag is generated
	WIF – When one (or more) satellite(s) elevation angle is less than 5 degrees, the warning integrity flag is generated
Multipath	***CIF*** – When the ELP exceeds 0.1 radians, the caution integrity flag is generated
	WIF – When the multipath ranging error exceeds 2 metres and the A/C flies in proximity of the ground (below 448.5 metres) the warning integrity flag is generated
Tracking loops	***CIF*** – When either $42.25° \leq 3\sigma_{\mathrm{PLL}} \leq 45^{\circ}$ or $0.2375\mathrm{T} \leq 3\sigma_{\mathrm{FLL}} \leq 0.25\mathrm{T}$ or $0.05\mathrm{d} \leq 3\sigma_{\mathrm{DLL}} \leq \mathrm{d}$, the CIF is generated
	WIF – When $3\sigma_{\mathrm{PLL}} > 45^{\circ}$ or $3\sigma_{\mathrm{FLL}} > 1/4\mathrm{T}$ or $3\sigma_{\mathrm{DLL}} > \mathrm{d}$ the WIF is generated
C/N_0	***CIF*** – When the C/N_0 is less than 26 dB-Hz the CIF is generated
	WIF – When the C/N_0 is less than 25 dB-Hz the CIF is generated
Jamming	***CIF*** – When the difference between the received (incident) jammer power (dBw) and the received (incident) signal power (dBw) is 1 dB below the J/S performance of the receiver at its tracking threshold, the CIF is generated
	WIF – When the difference between the received (incident) jammer power (dBw) and the received (incident) signal power (dBw) is above the J/S performance of the receiver at its tracking threshold, the WIF is generated
Doppler	***CIF*** – When the C/N_0 is below 28 dB-Hz and the signal is lost, the caution integrity flag is generated if the estimated acquisition time is less than the application-specific TTA requirements
	WIF – When the C/N_0 is below 28 dB-Hz and the signal is lost, the warning integrity flag is generated if the estimated acquisition time exceeds the application-specific TTA requirements

ABIA IFG Simulation

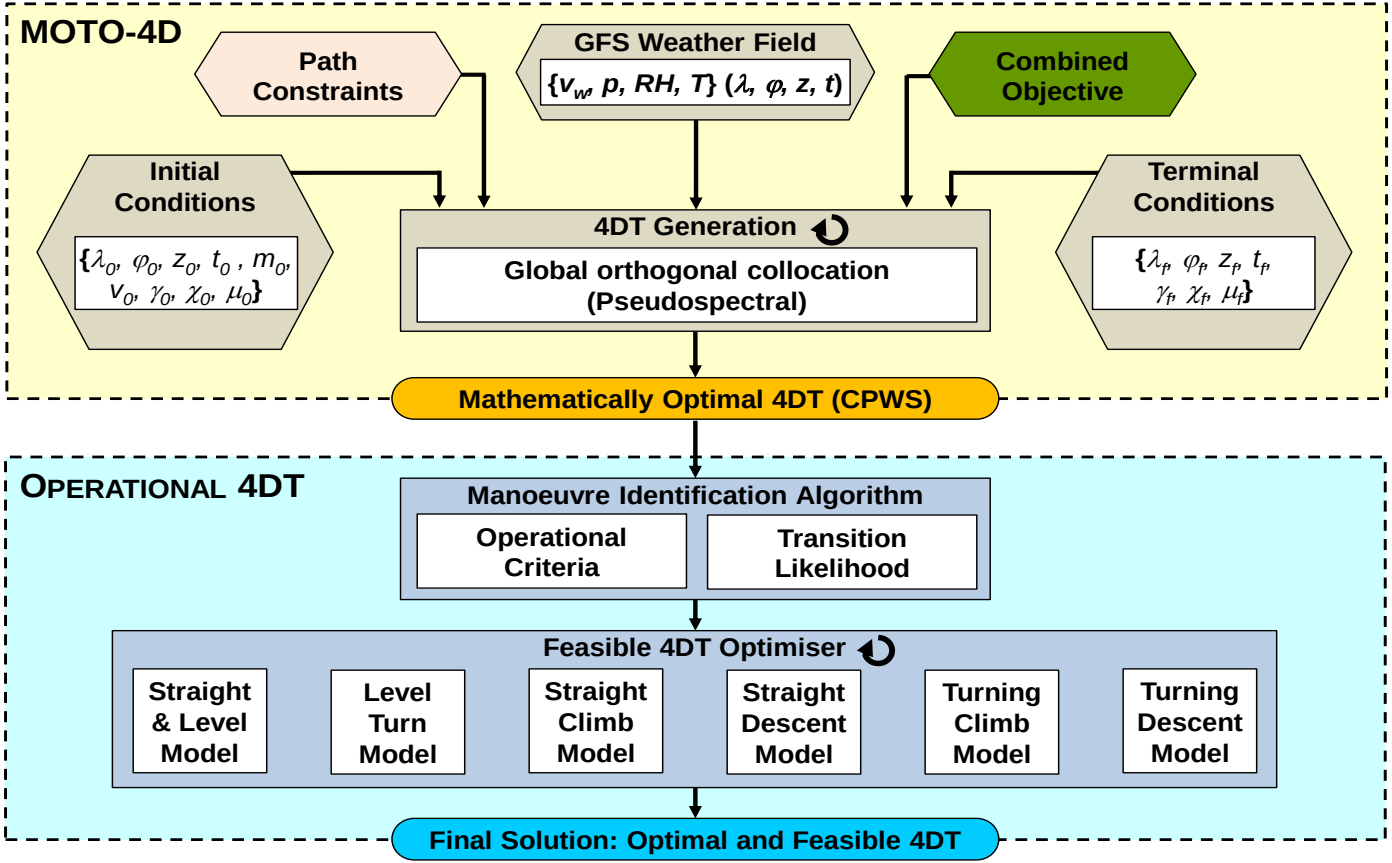
FLIGHT LEG	CIF Time	WIF Time
Straight Climb	---	---
Turning Climb	---	---
Straight & Level	---	---
Level Turn	2241 ~ 2311 s, 2413 ~ 2485 s, 2491 ~ 2650 s	2259 ~ 2263 s, 2273 ~ 2283 s, 2432 ~ 2436 s, 2446 ~ 2485 s, 2609 ~ 2612 s, 2621 ~ 2630 s
Turning Descent	2688 ~ 2752 s, 2811 ~ 2881 s, 2944 ~ 3012 s, 3079 ~ 3100 s	2690 ~ 2739 s, 2814 ~ 2869 s, 2946 ~ 3003 s, 3081 ~ 3100 s
Straight Descent	---	---
Approach	3301 ~ 3400 s	3303 ~ 3400 s



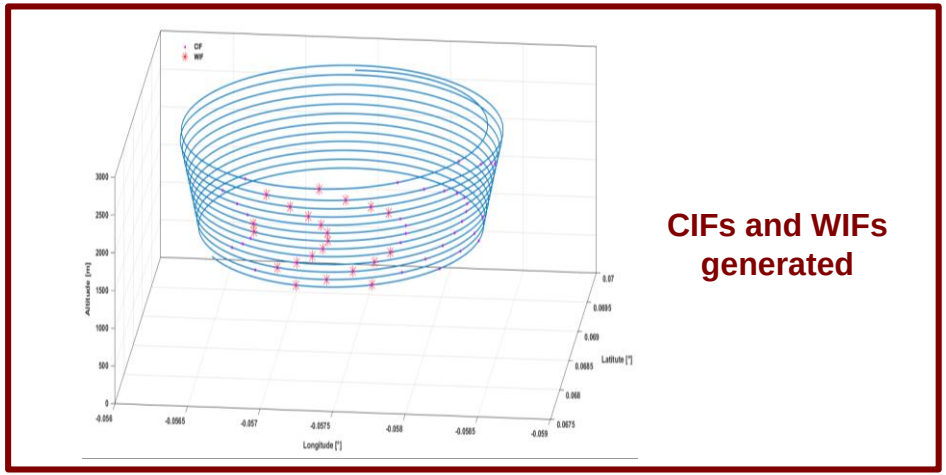
ABIA IFG Simulation (2)



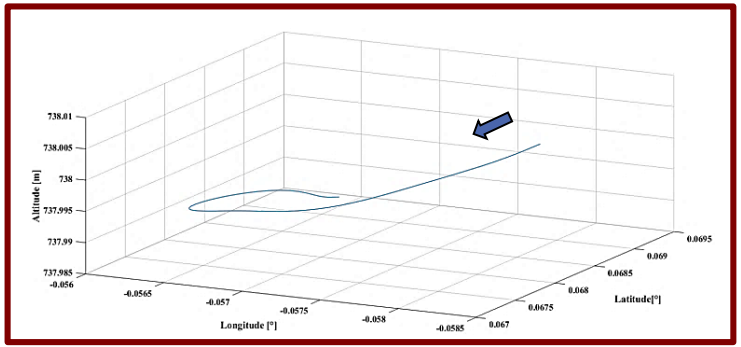
Online Tactical 4DT Planning Algorithm



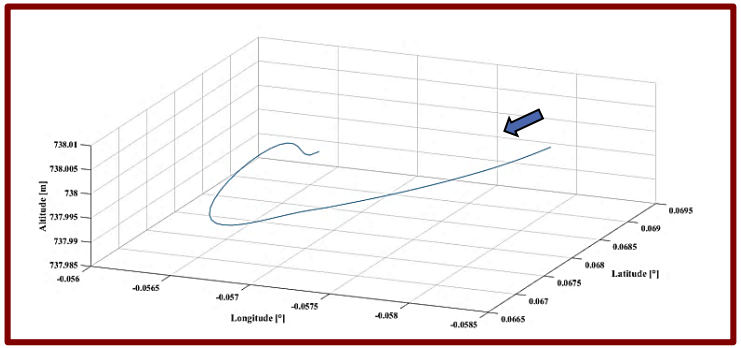
Trajectory Optimization Results



CIFs and WIFs generated



TD leg segment optimised with PMO

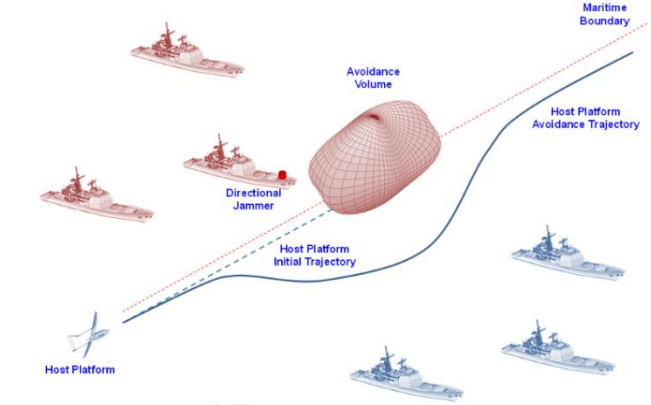


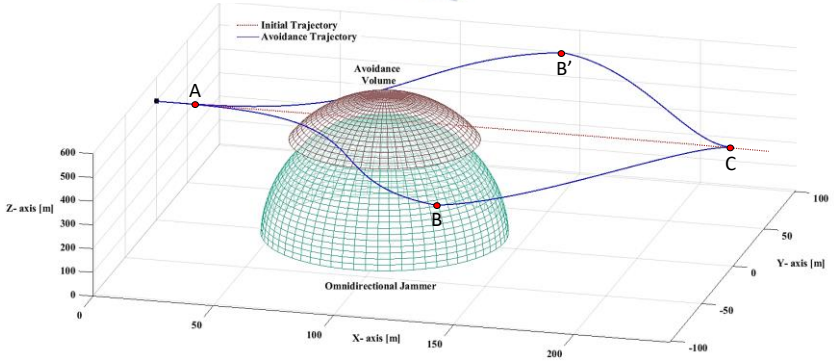
TD leg segment optimised with CGO

- CIF not followed by WIF
  - Pseudo-spectral methods produce quasi real-time solutions (acceptable for mission planning and some flight management implementations)
  - More efficient (real-time) geometric algorithms are used in other cases

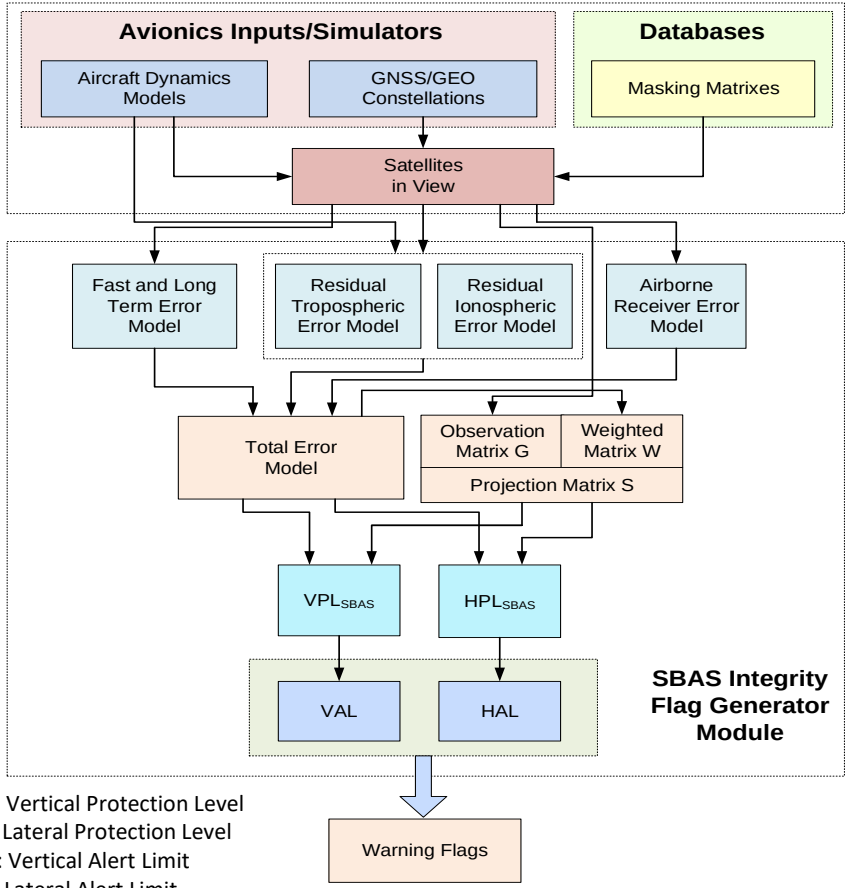
Autonomous Navigation and Guidance in GNSS-denied and Challenged Environments

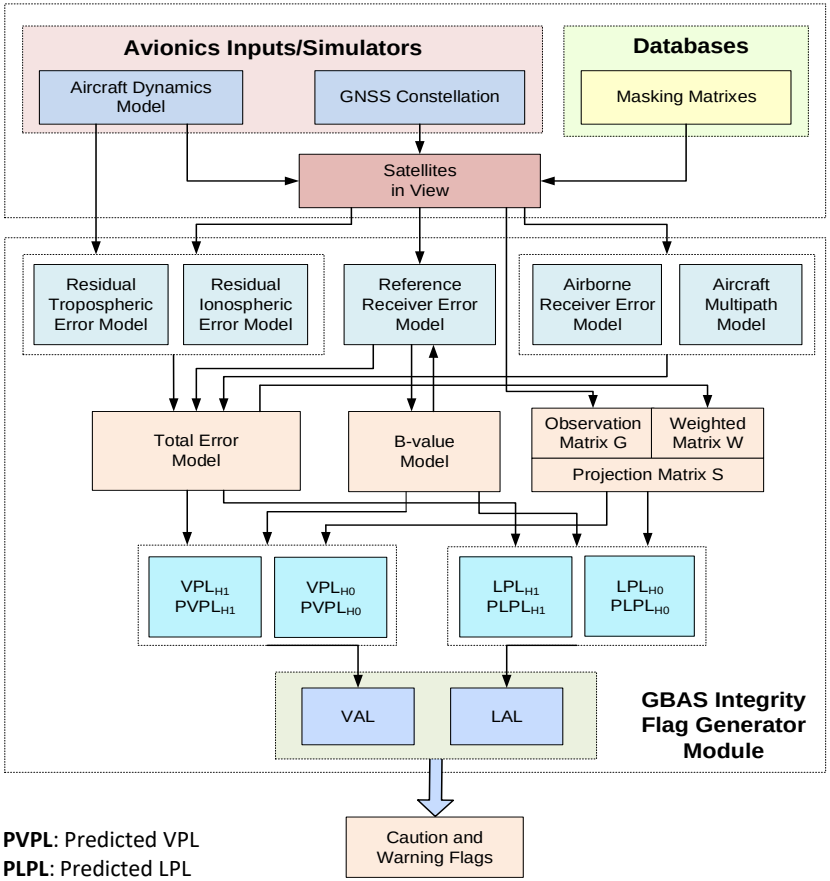
- Jamming radiation pattern estimated based on J/S, C/N_0 and jammer type
- Development of ABAS-based predictions to avoid jamming volume
- Generation of optimal avoidance trajectories, preventing degradation or losses of navigation data





SBAS and GBAS IFG Architectures

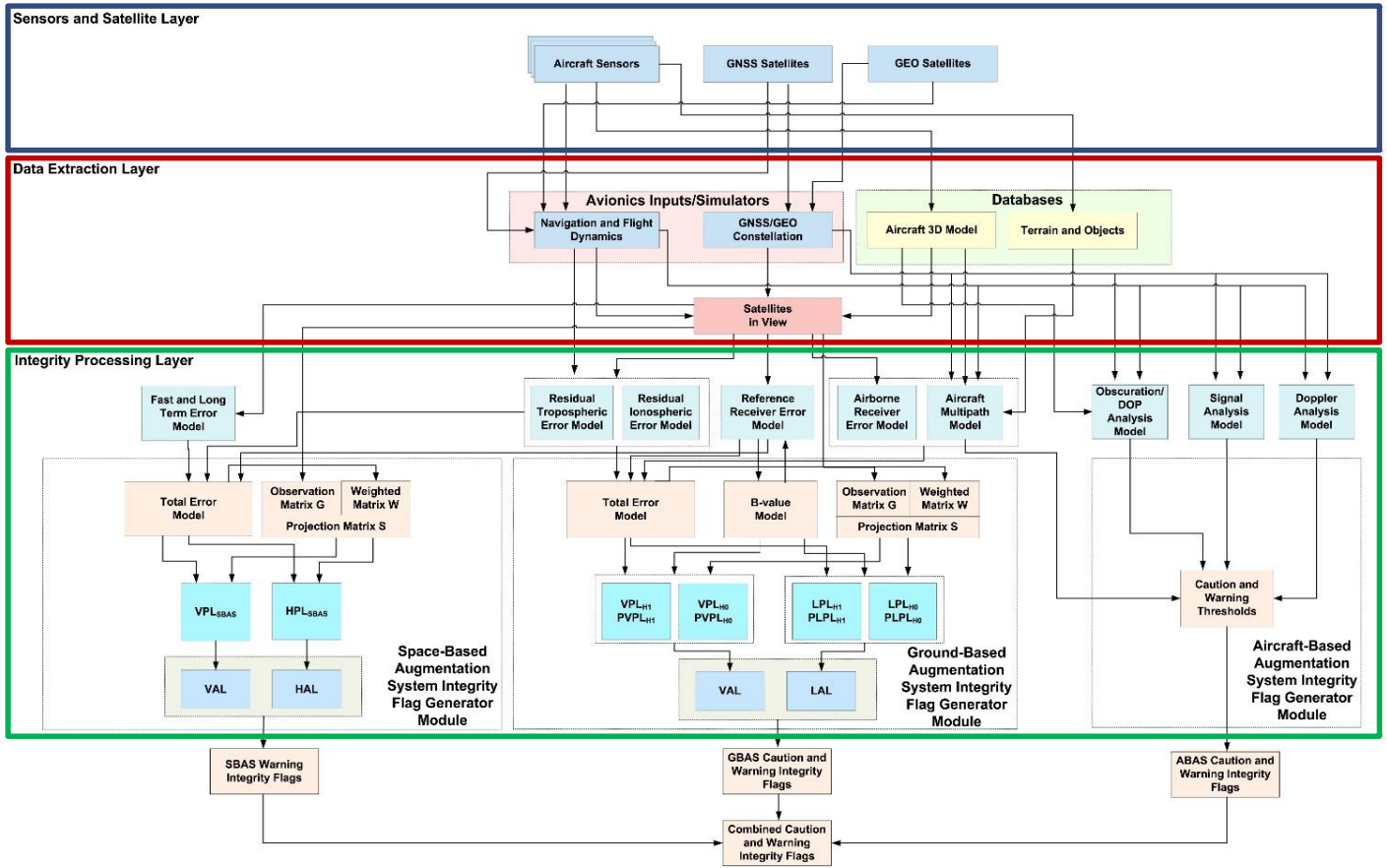




VPL: Vertical Protection Level
LPL: Lateral Protection Level
VAL: Vertical Alert Limit
LAL: Lateral Alert Limit

PVPL: Predicted VPL
PLPL: Predicted LPL

Space-Ground-Aircraft Augmentation Network

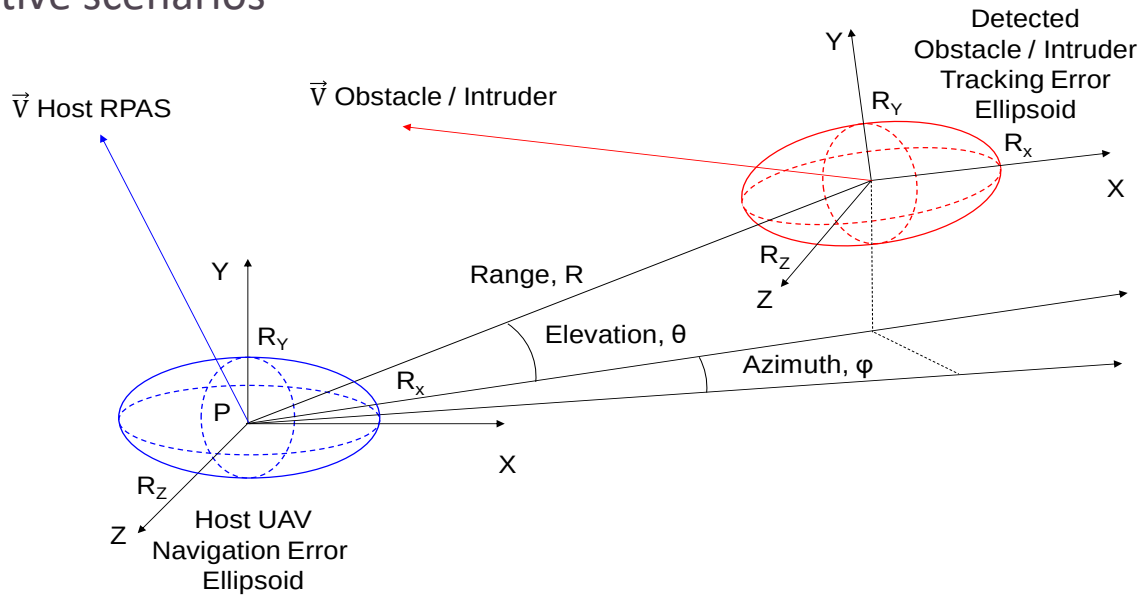


VPL: Vertical Protection Level
LPL: Lateral Protection Level
VAL: Vertical Alert Limit
LAL: Lateral Alert Limit
PVPL: Predicted VPL
PLPL: Predicted LPL

Separation Assurance and Collision Avoidance Systems

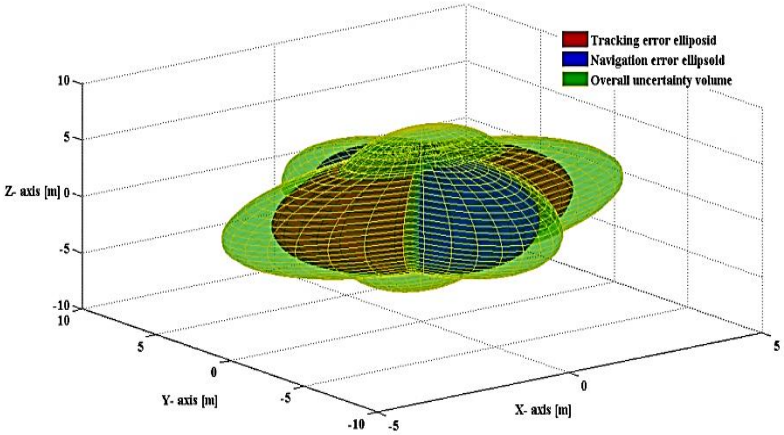
Separation Assurance and Collison Avoidance

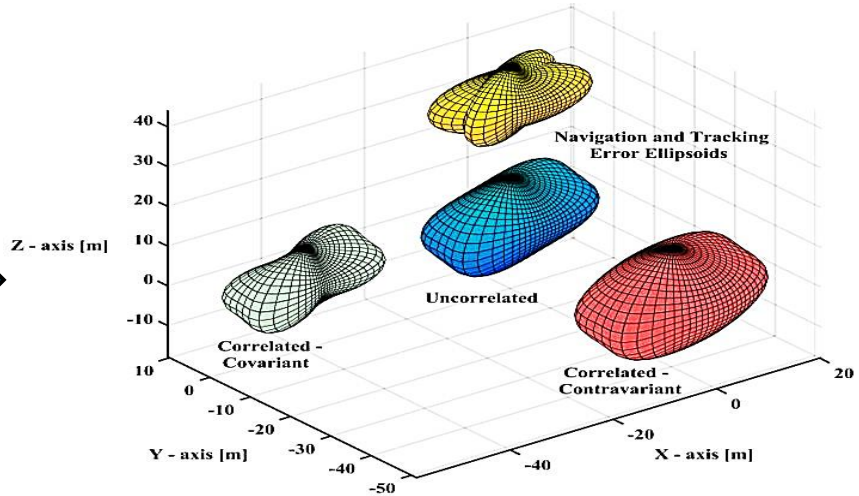
- **Avoidance volume** in the airspace surrounding each track is determined
- Accomplished by **considering both navigation and tracking errors** affecting the measurements (plus disturbances) and translating them to **unified range and bearing uncertainty descriptors**, which apply both to cooperative and non-cooperative scenarios



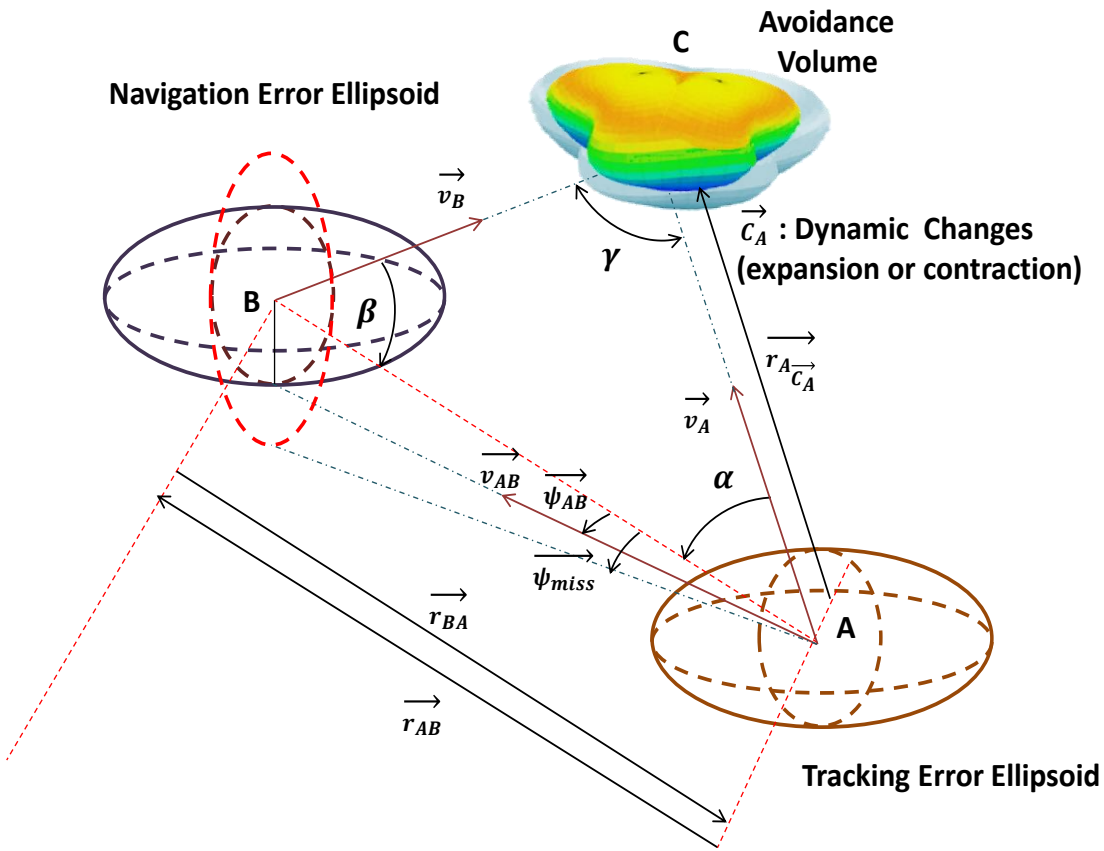
SA/CA – Error Analysis

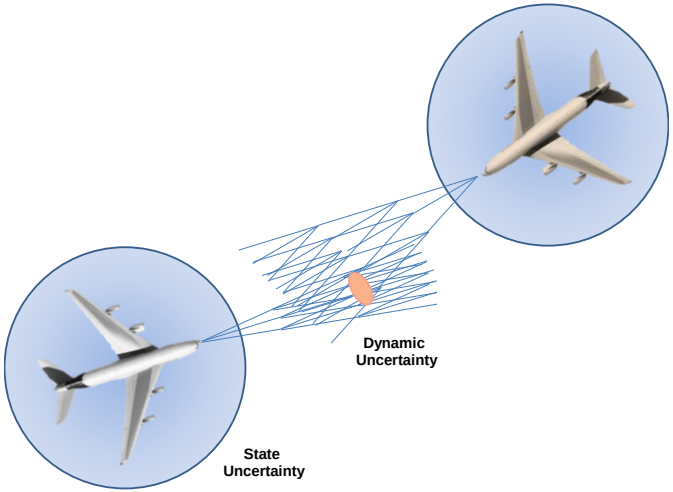
- Errors are statistically correlated (e.g., ADS-B) or uncorrelated (e.g., NC-SAA)
- The avoidance (uncertainty) volume for uncorrelated measurements is obtained by inflating the navigation ellipsoid with the tracking error components
- The uncertainty volume for correlated errors is obtained using vector analysis





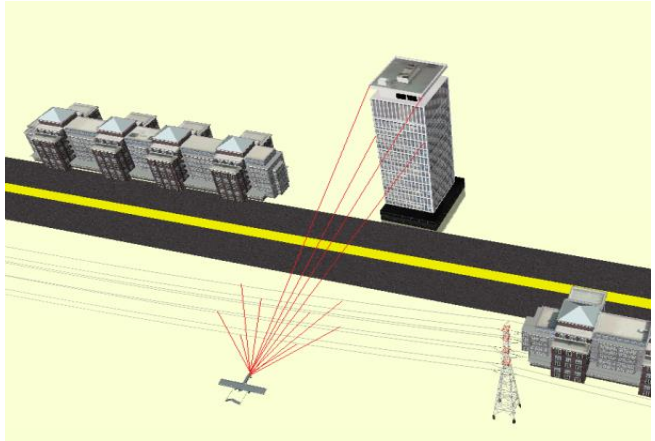
SA/CA – Relative Dynamics and Inflations

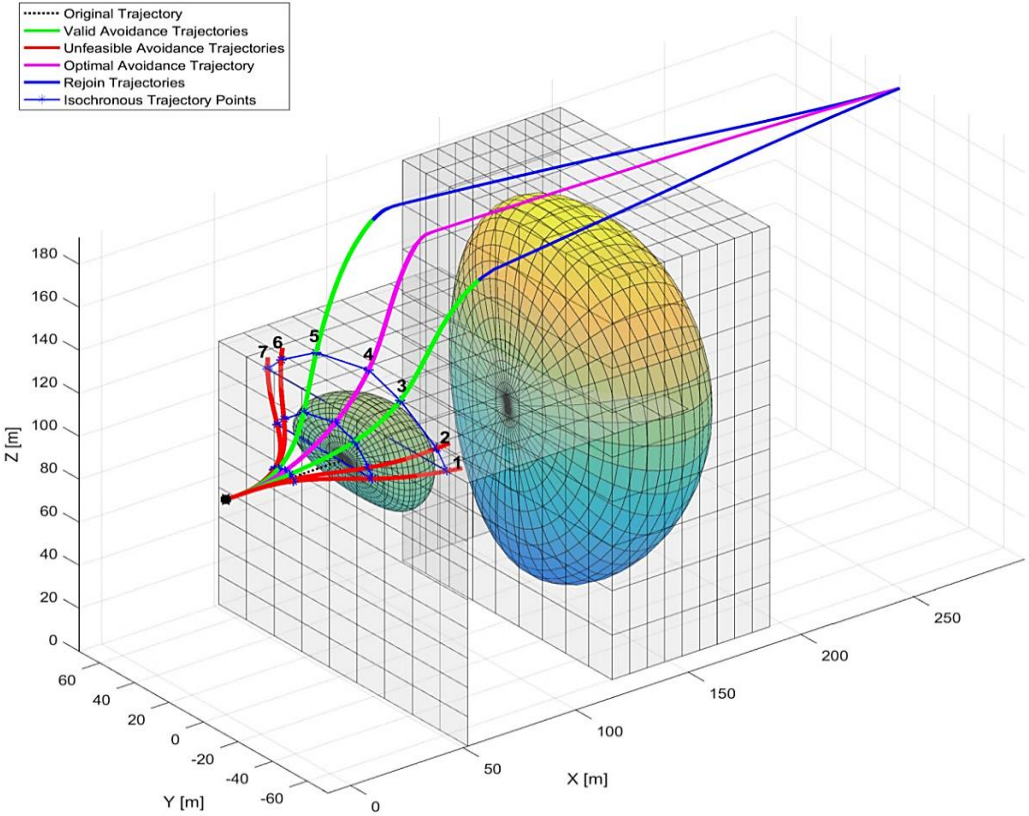




SA/CA – Safety-critical Applications

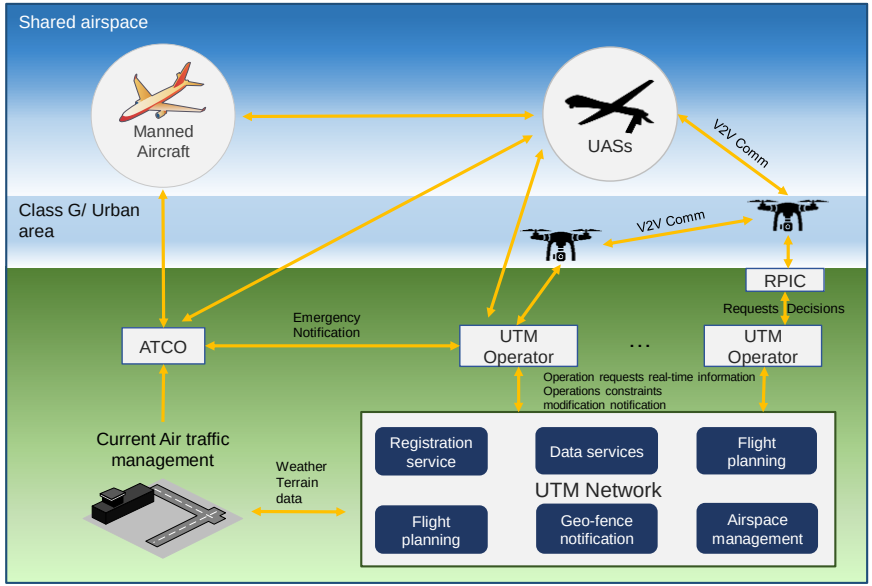
- Uncertainty volumes for avoidance of ground obstacles
  - A set of feasible avoidance trajectories is generated in real-time

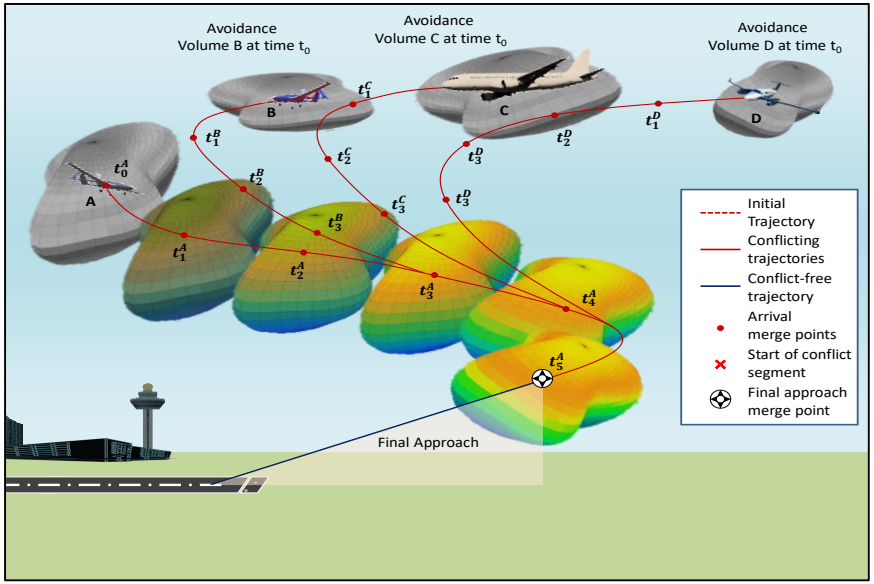




UAS Traffic Management

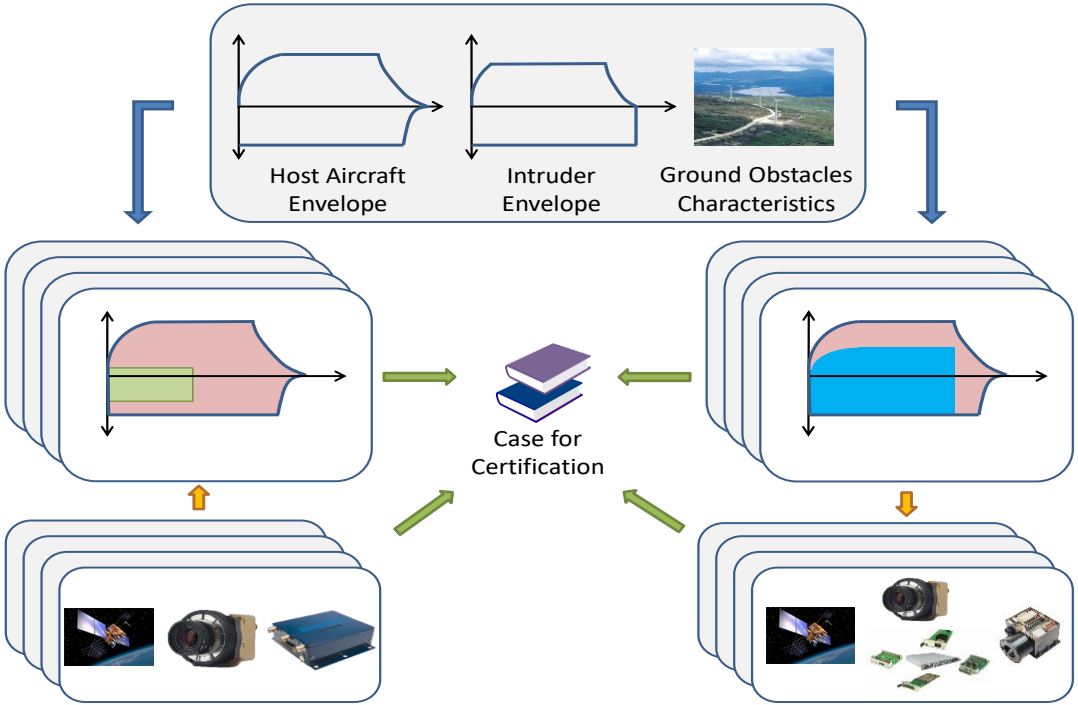
- The unified approach supports trusted autonomous operations in the UAS Traffic Management (UTM) context
- Avoidance volumes (i.e., dynamic geo-fences) are generated in real-time to allow computation of the optimal avoidance flight trajectories

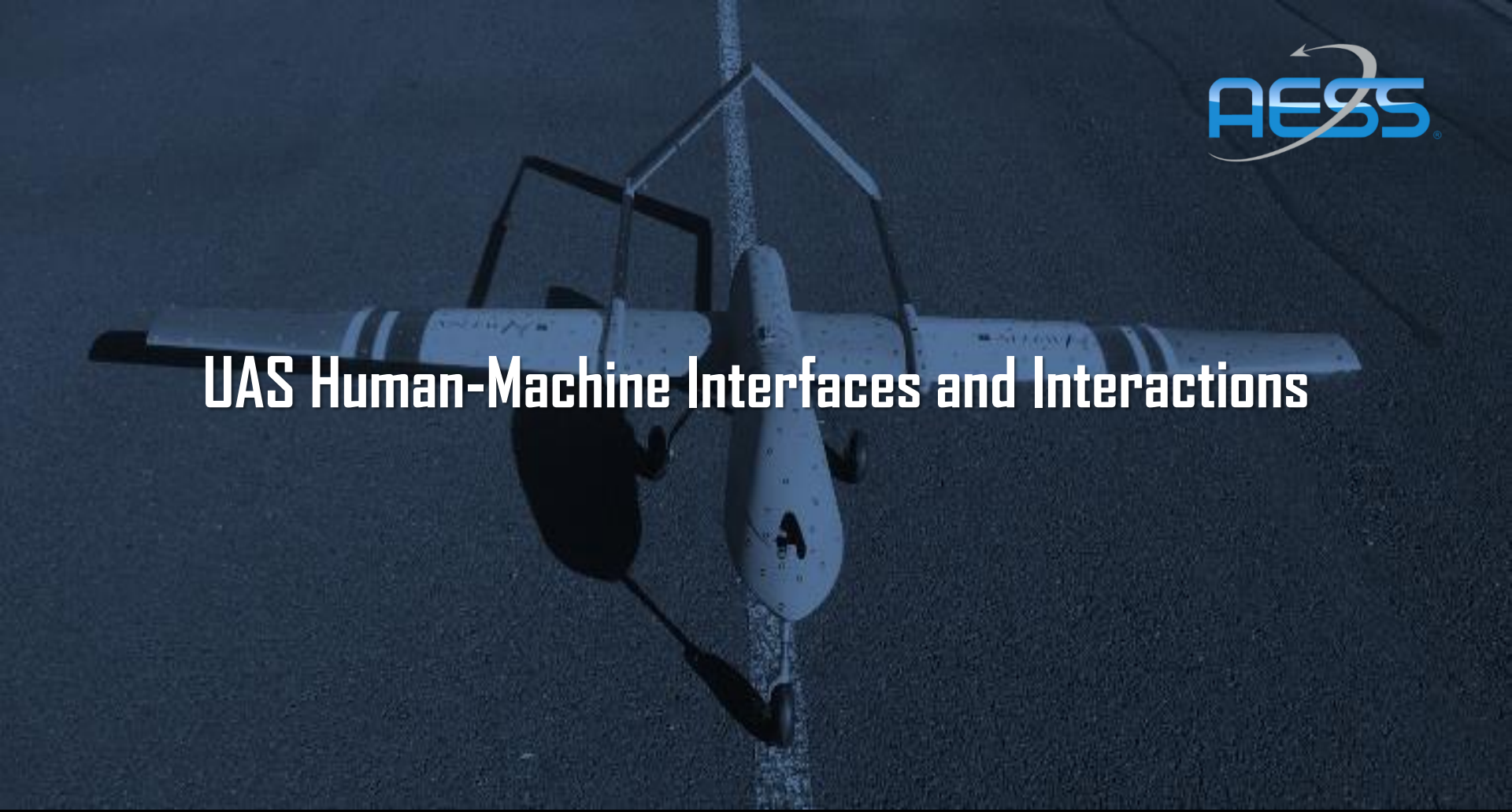




SA/CA – Pathway to Certification

- Distinctive advantage: ability to determine the safe-to-fly UAS envelope based on the on-board sensors and alternatively to identify the required sensors in order to achieve a certain predefined safety envelope

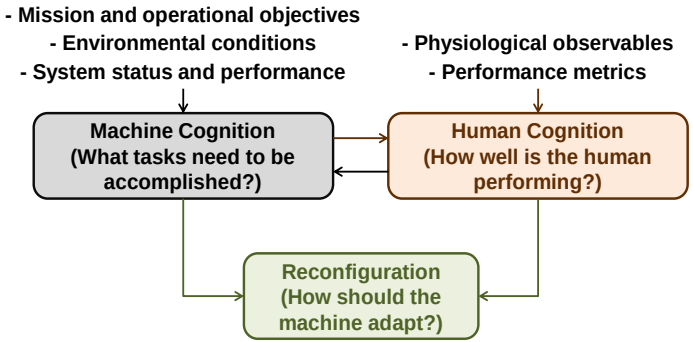




UAS Human-Machine Interfaces and Interactions

UAS Human-Machine Interfaces and Interactions

- This project addresses the development of closed-loop human-machine systems implementing Cognitive Human Machine Interfaces and Interactions ($CHMI^2$)
- $CHMI^2$ supports human-machine teaming whereby a system senses and adapts to the mission environment and the cognitive state of the operator

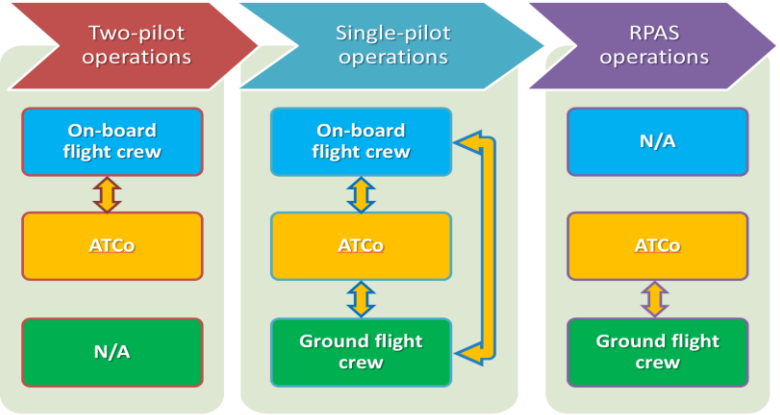


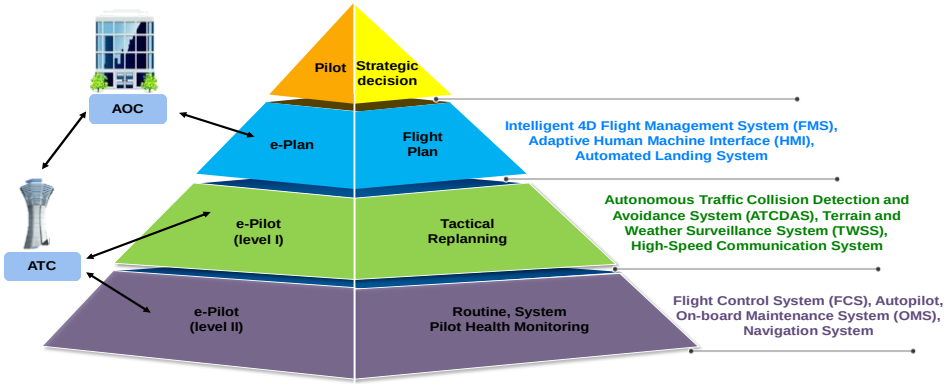
- The $CHMI^2$ concept enables **<u>Trusted Autonomous Operations</u>** in both mission-critical and safety-critical applications

CHMI^2 Aeronautical Applications

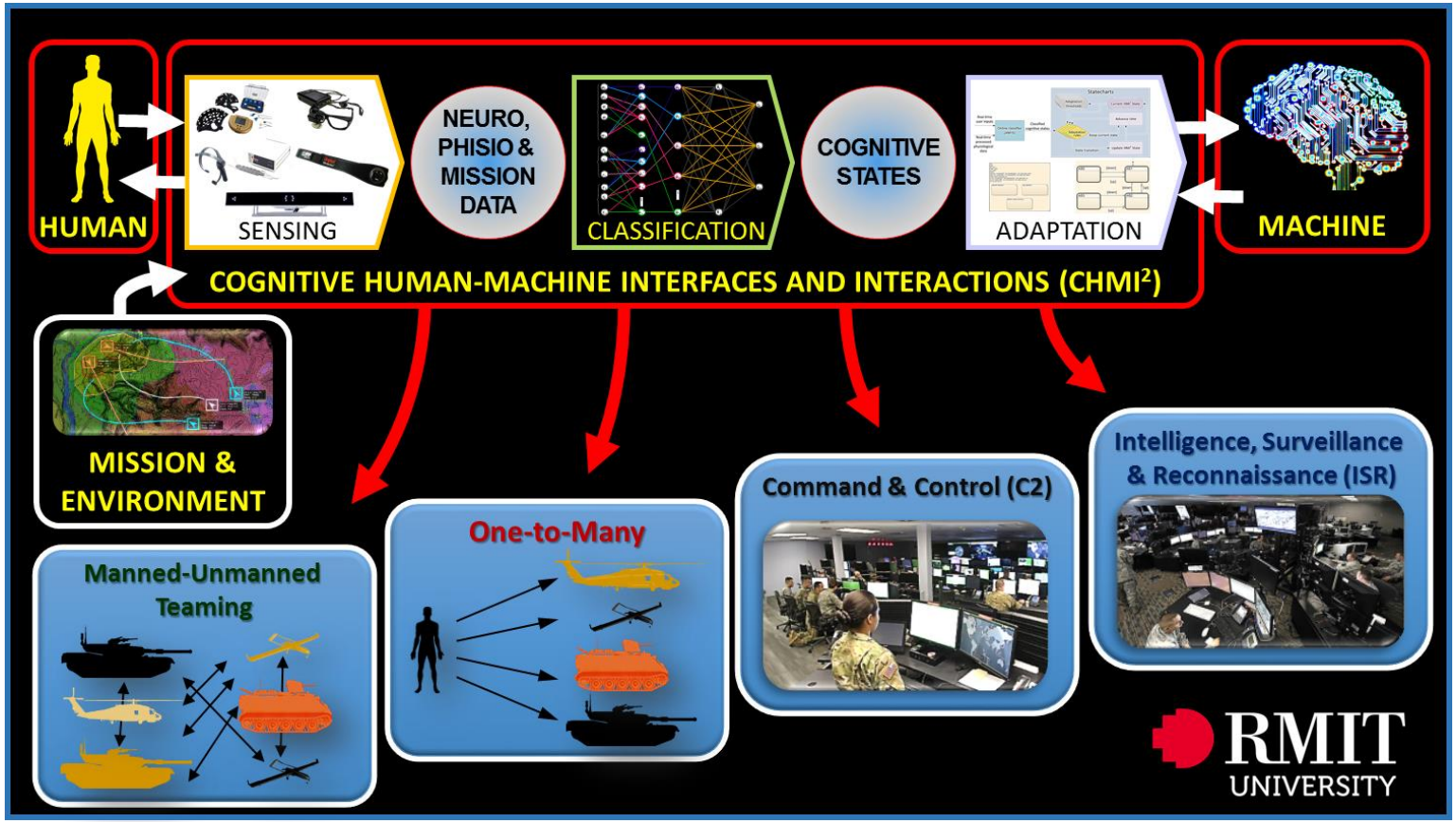
❖ System Requirements

- Increase CNS+A efficiency by dynamically assisting human operators based on real-time detection of physiological and cognitive states
- To improve the total system performance by facilitating human-machine teaming
- To provide clear and unambiguous display formats and functions (system modes, sub-modes and data) based on the operator's estimated cognitive states

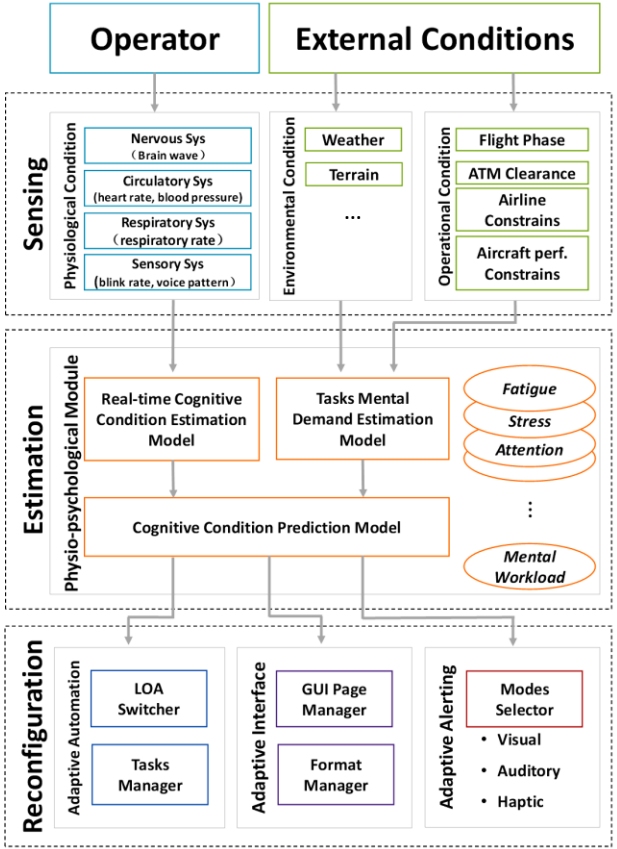




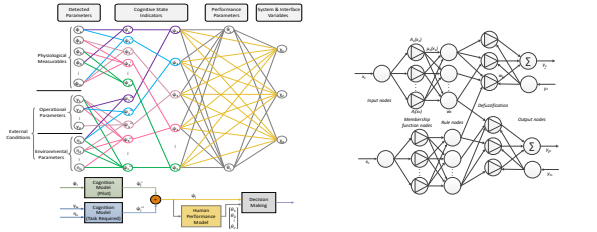
CHMI^2 Defence Applications



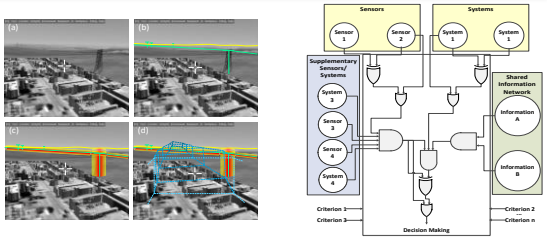
CHMI^2 Framework



Sensing: uses a suite of sensors to measure neuro-physiological observables in real time, and extracts relevant features from the observables



Inference: infers cognitive states from the features in the sensing layer using various artificial intelligence (and machine learning) techniques



Adaptation: module drives the HMI^2 based on inferred cognitive states and key mission performance metrics

CHMI² Mathematical Framework

ϕ_1 (Heart Rate)
ϕ_2 (Blood Pressure)
ϕ_3 (Blink Rate)
ϕ_4 (Blink Duration)
⋮
ϕ_m (Respiration Rate)

$$\psi'_{j,t} = f(\varphi_{i,t})$$

$$\psi_{j,ref}{}' = f(\varphi_{i,ref})$$

$$\psi'_j = \sum_{i=1}^{n} \alpha_i \cdot \frac{\psi_{j,t}' - \psi_{j,ref}'}{\psi_{j,ref}'}$$

$\psi_1{}'$ (Vigilance)
$\psi_2{}'$ (Arousal)
$\psi_3{}'$ (Workload)
$\psi_4{}'$ (Stress)
⋮
$\psi_n{}'$ (Fatigue)

ψ_1 (Vigilance)
ψ_2 (Arousal)
ψ_3 (Workload)
ψ_4 (Stress)
⋮
ψ_n (Fatigue)

$$\begin{bmatrix}\theta_1\\ \theta_2\\ \vdots\\ \theta_c\end{bmatrix} = \begin{bmatrix}\beta_{11} & \beta_{12} & \cdots & \beta_{1n}\\ \beta_{21} & \beta_{22} & \cdots & \beta_{2n}\\ \vdots & \vdots & \ddots & \vdots\\ \beta_{c1} & \beta_{l2} & \cdots & \beta_{cn}\end{bmatrix}\begin{bmatrix}\psi_1\\ \psi_2\\ \vdots\\ \psi_n\end{bmatrix} + \begin{bmatrix}\theta_1\\ \theta_2\\ \vdots\\ \theta_c\end{bmatrix}_0$$

Θ_1 (Error Rate)
Θ_2 (Reaction Time)
Θ_3 (Search Time)
Θ_4 (Action Time)
⋮
Θ_c (Time to Complete)

γ_1 (ATM clearance)
γ_2 (Airline constraints)
⋮
γ_p (Air traffic complexity)

η_1 (Weather complexity)
⋮
η_q (Terrain complexity)

$$\psi''_j = \sum_{w=1}^{p} \alpha_w \cdot \frac{\gamma_{w,t}}{\gamma_{w,t-1}} + \sum_{v=1}^{q} \alpha_v \cdot \frac{\eta_{v,t}}{\eta_{v,t-1}}$$

$\psi_1{}''$ (Vigilance)
$\psi_2{}''$ (Workload)
$\psi_3{}''$ (Stress)
$\psi_4{}''$ (Fatigue)
⋮
$\psi_n{}''$ (Arousal)

Linear models

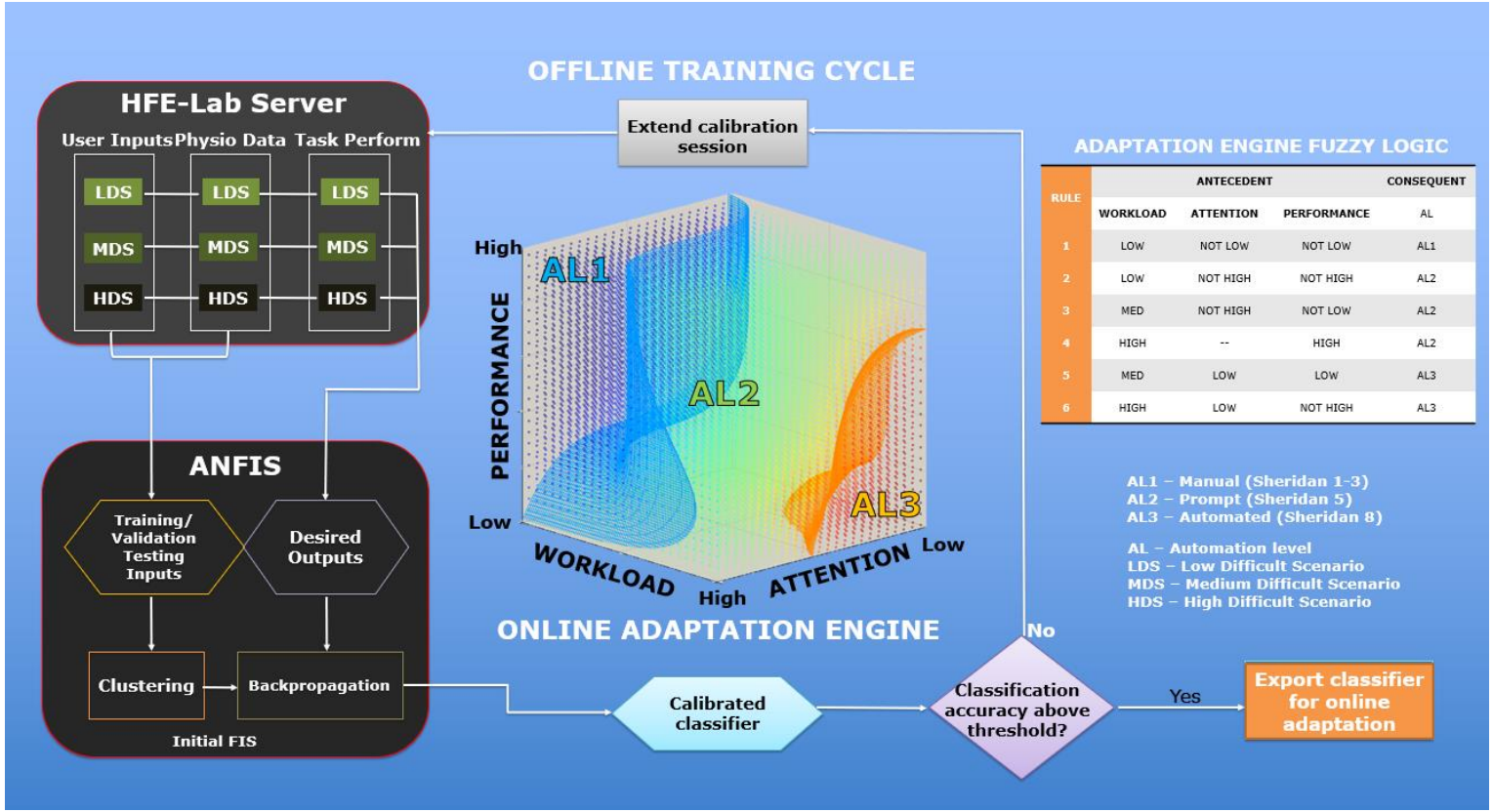
Non-linear models

	Fixation time	Glance count	Saccade dispersion	Dwell time	Visual Entropy	Pupil dilation	Heart rate	Resp. Rate	Blink rate
Vigilance	Q-N	L-P	Q-N	Q-N	Q-N	L-P	-	-	L-N
Workload	SPL-P	-	L-N	SPL-P	L-N	L-P	L-P	L-P	L-N
Attention	L-P	SBL-N	L-N	L-P	L-N	L-P	SPL-P	-	L-N

	Vigilance	Workload	Attention
Error rate	L-N	SPL-P	L-N
Reaction time	L-N	Q-P	Q-P
Situational awareness	L-P	Q-N	L-N
Efficiency	L-P	SBL-N	Q-N
Precision	L-P	SBL-N	L-P

Inference Engine

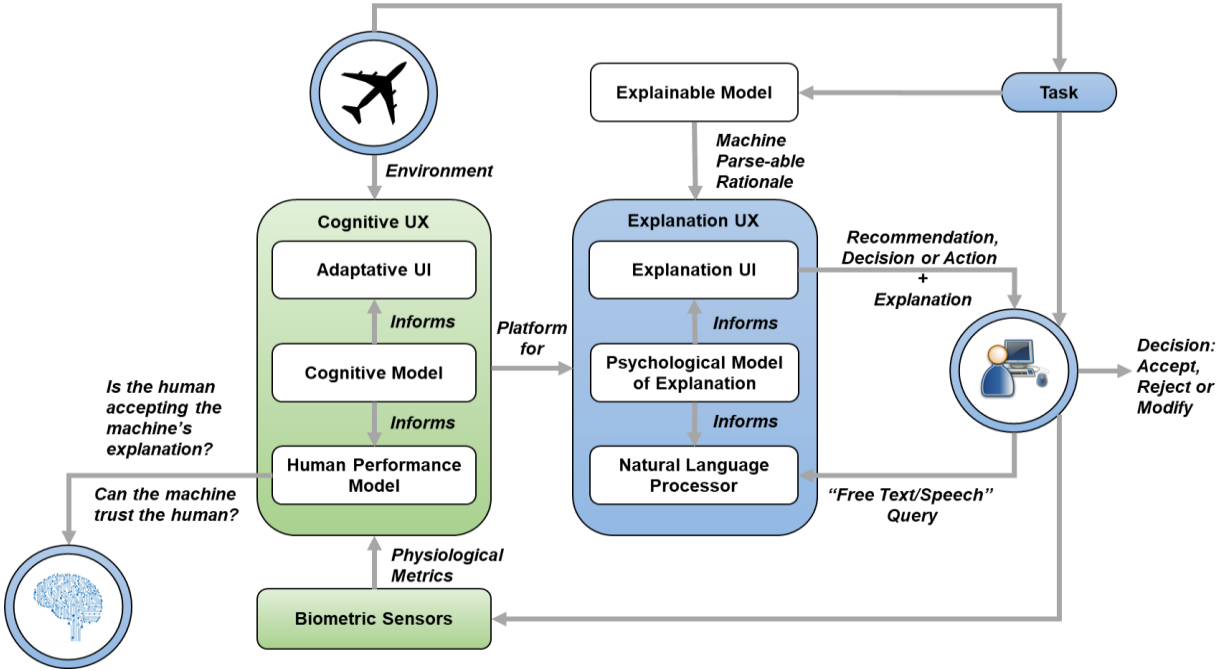
Cognitive Adaptation Methodology (Summary View)



ADAPTATION ENGINE FUZZY LOGIC

RULE	ANTECEDENT			CONSEQUENT
	WORKLOAD	ATTENTION	PERFORMANCE	AL
1	LOW	NOT LOW	NOT LOW	AL1
2	LOW	NOT HIGH	NOT HIGH	AL2
3	MED	NOT HIGH	NOT LOW	AL2
4	HIGH	--	HIGH	AL2
5	MED	LOW	LOW	AL3
6	HIGH	LOW	NOT HIGH	AL3

Current Research: Cognitive HMI and Explanation UX



- **Explainable AI**
- **Trusted AI**
- **Certifiable AI**

Cybersecurity Challenges

Evolving ATM Cyber-Landscape

- Over the last three decades, the "cyber-landscape" in ATM has evolved significantly, particularly in conjunction with:
  - a continuing migration from dedicated to **general-purpose hardware**, including PCs, rack servers, tablets, laptops and even personal mobile devices, to which a growing number of COTS wireless devices are connected (incl. headsets, input devices, printers etc.)
  - a continuing migration from a dedicated and largely domestic-only Aeronautical Fixed Telecommunication Networks (AFTN) towards **global IP-based connectivity**
  - the ongoing implementation of new **SESAR and NextGen technologies**, most of which are data-link-based or terrestrial IP-based technologies (incl. SWIM, VDL, 4D-TRAD, AeroMACS, A-CDM etc.)
- The future of ATM (and especially UTM) involves substantially greater amounts of data exchanged in real-time across an increasing number of stakeholders

Security - Protecting Operations/Applications, Protecting Communications, Protecting Data

Cybersecurity

- **Privacy** – preventing eavesdropping
- **Authentication** – proof that a person or message is what it purports to be
- **Authorization** – allowing only certain access or behaviors

Physical Security

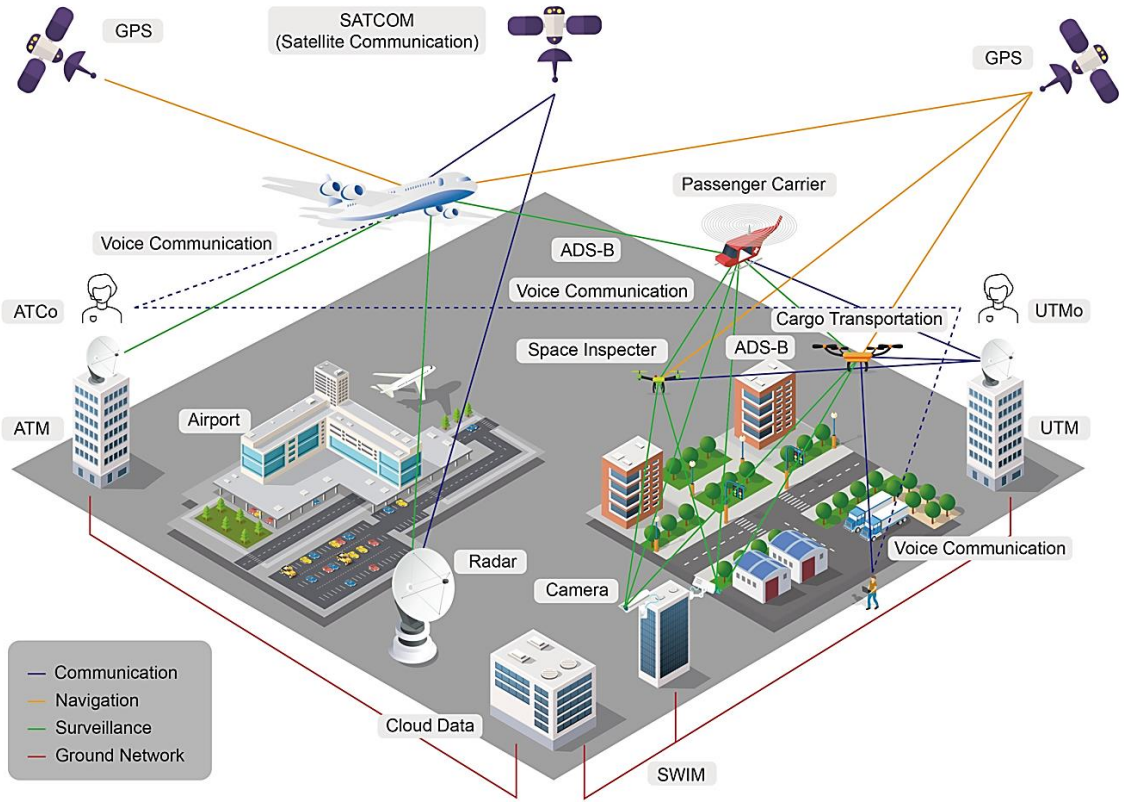
- Often, a lack of physical security facilitates cyber attacks. Physical safeguards can reduce vulnerability

Cyber-Physical Systems

- Significant in the context of UAS avionics
- Trustworthy AI?

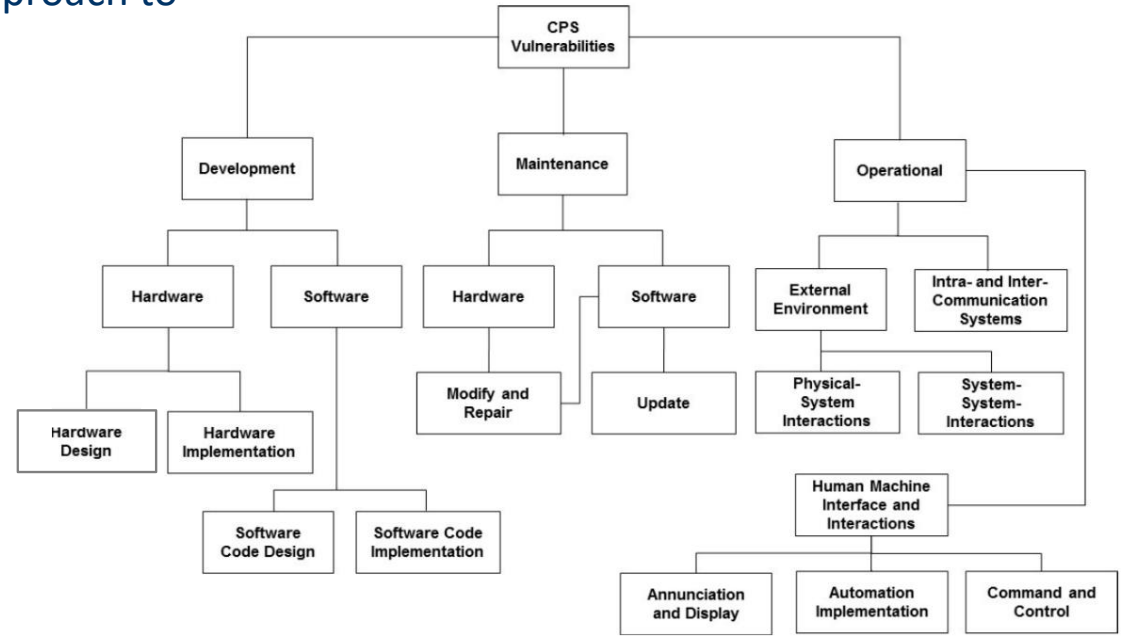
Cybersecurity Vulnerabilities in ATM and UTM

- Communication
  - HF/VHF voice, CPDLC, L-DACS, ACARS
  - SATCOM, Wireless communication networks
- Navigation
  - TRNAs, GNSS
- Surveillance
  - PSR, SSR, WAM, TACS, ADS-B
- Ground Network
  - SWIM



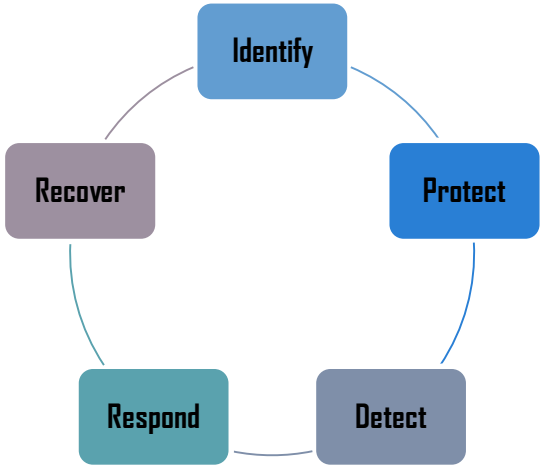
Vulnerability Assessment

- STRIDE is an abbreviation for various known attack paths, one standard approach to assess vulnerabilities:
  - **S**poofing Identity
  - **T**ampering with Data
  - **R**epudiation
  - **I**nformation Disclosure
  - **D**enial of Service
  - **E**levation of Privilege



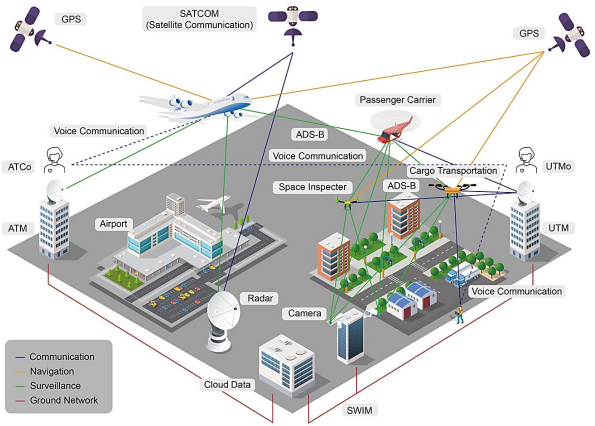
UAS Attack Surface and Cybersecurity Framework

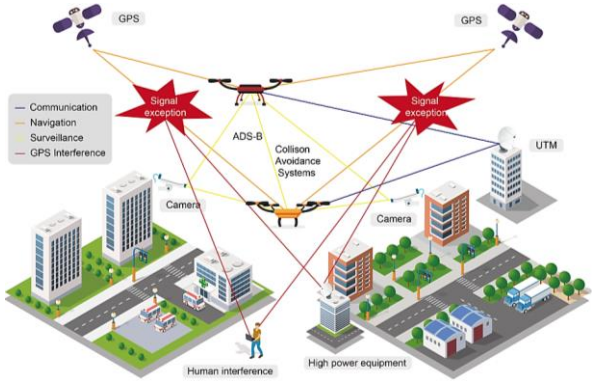
Segment	Vulnerability	Threats
Unmanned Aircraft	Payload Vulnerabilities	• Denial of Service • Hardware Backdoor • Bespoke Malware • Privilege Escalation • Hijacking • Sensor Injection
Comms/C2 Link	Signal Vulnerabilities	• Jamming • Eavesdropping • Spoofing • Metadata-Analysis • Command Injection • Replay Attacks • Signal Injection
Ground Control (GCS and UTM)	GCS/UTM Vulnerabilities	• Bespoke Malware • Generic Malware • Social Engineering • Physical Access • Data Corruption • Hardware Backdoor



Key Challenges

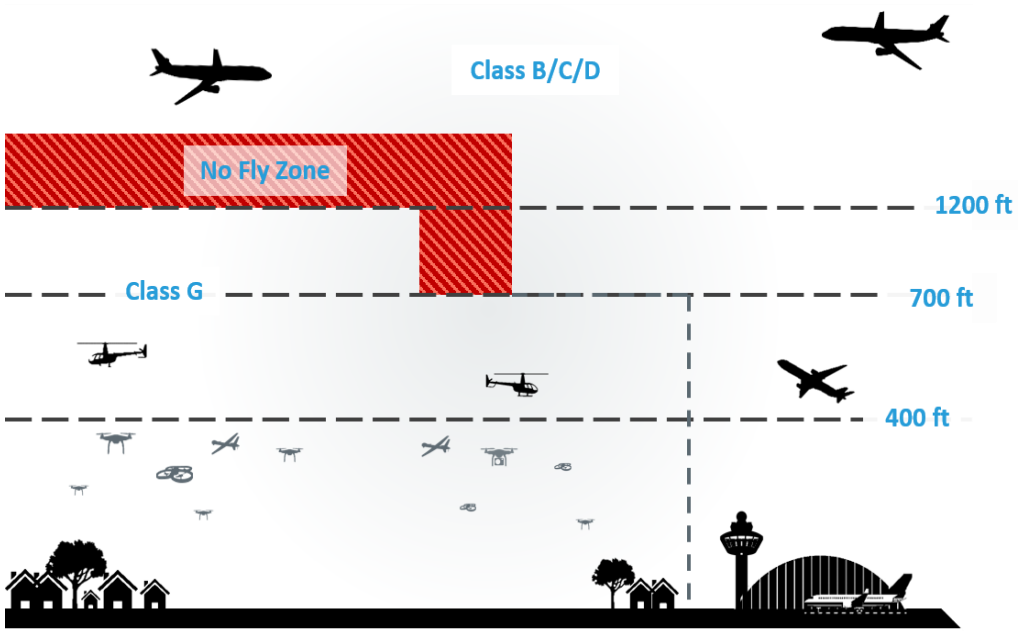
- Evolving ATM & UTM architectures based on big data and AI plus increased interdependence of CNS/ATM and avionics systems result in an increasing attack surface
- AI-based offensive technologies are bound to become very common, requiring AI-based cyber-defenses
- Need for a new generation of security management systems and more efficient attack detection techniques





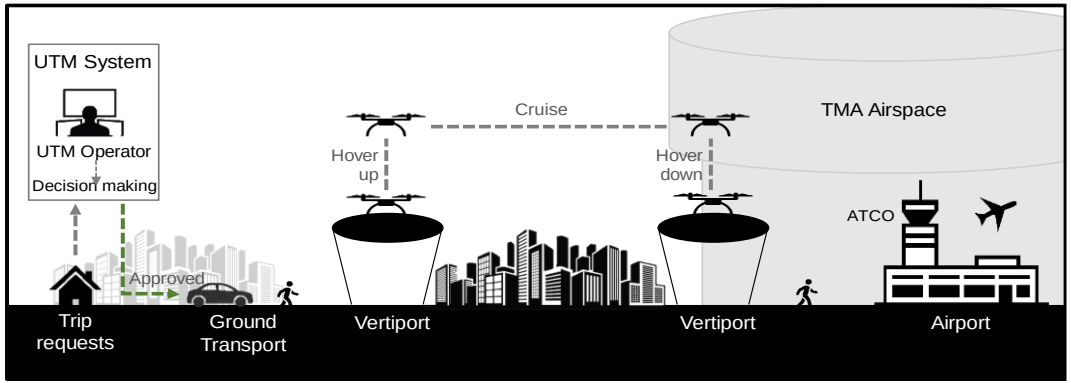
UTM and AAM Research Efforts

UAS Traffic Management (UTM) – Key Challenges



- The conventional human-intensive and tactical ATC paradigm cannot fulfil the needs of manned/UAS traffic integration
- A higher degree of automation is necessary in the UTM framework
- The tactical deconfliction approach of traditional ATM cannot be scaled down to apply in UTM
- The tasks and responsibilities of human UTM operators are not fully defined

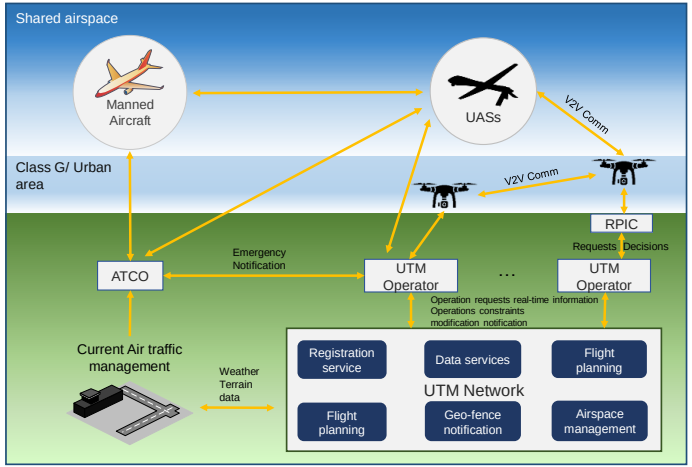
UTM and Advanced Air Mobility (AAM)



Advanced Air Mobility

A safe, automated air transportation system for passengers and cargo in urban and rural locations

- Regional Air Mobility (RAM)
- Urban Air Mobility (UAM)

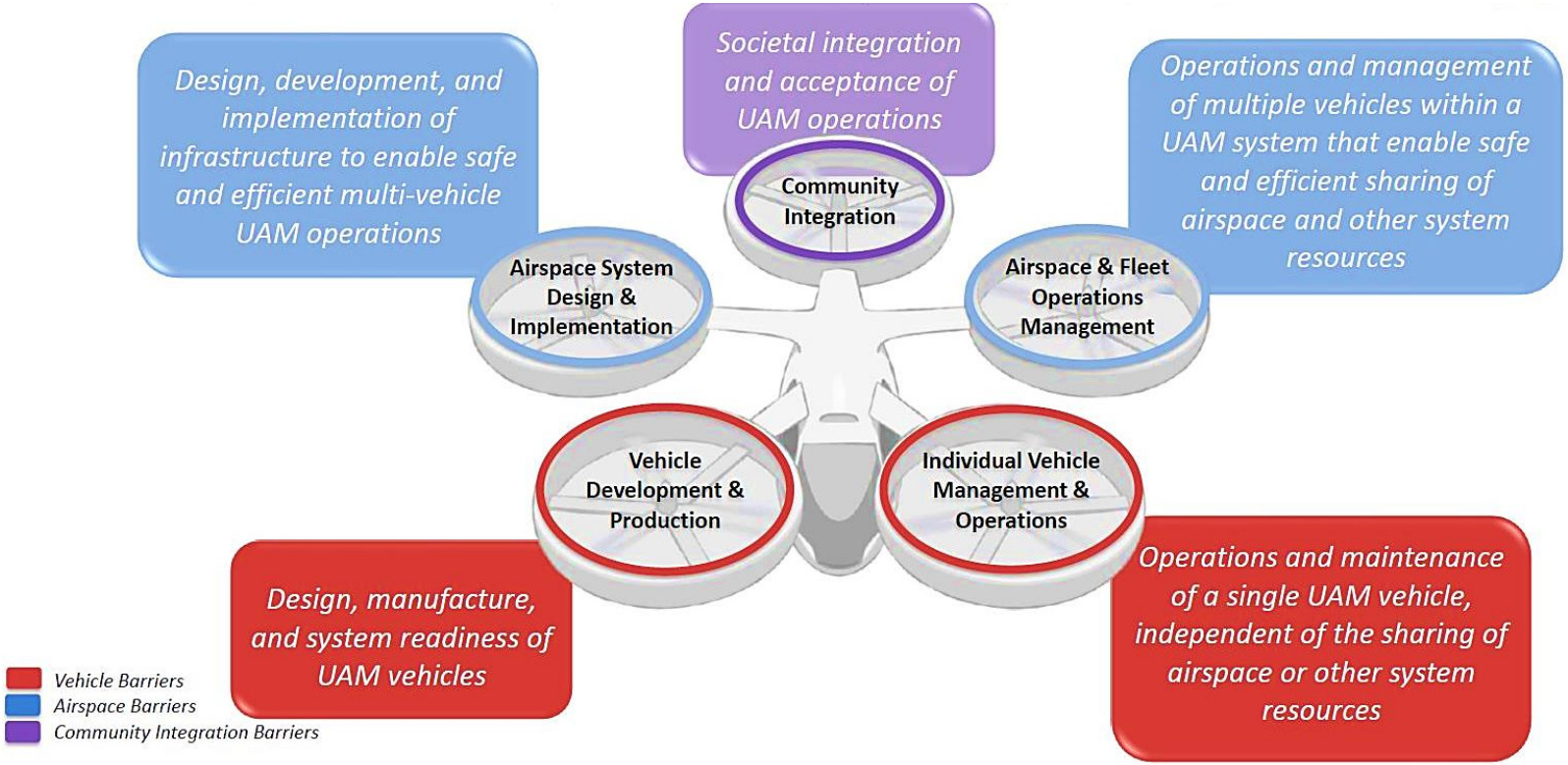


- UTM/AAM are moving towards trusted autonomy
- Highly automated human-in-the-loop operations bring about issues of responsibility allocation and mandate evolutions in the legal and regulatory frameworks (liability concerns)

The tasks and responsibilities of humans and AI agents in UTM/AAM are yet to be defined

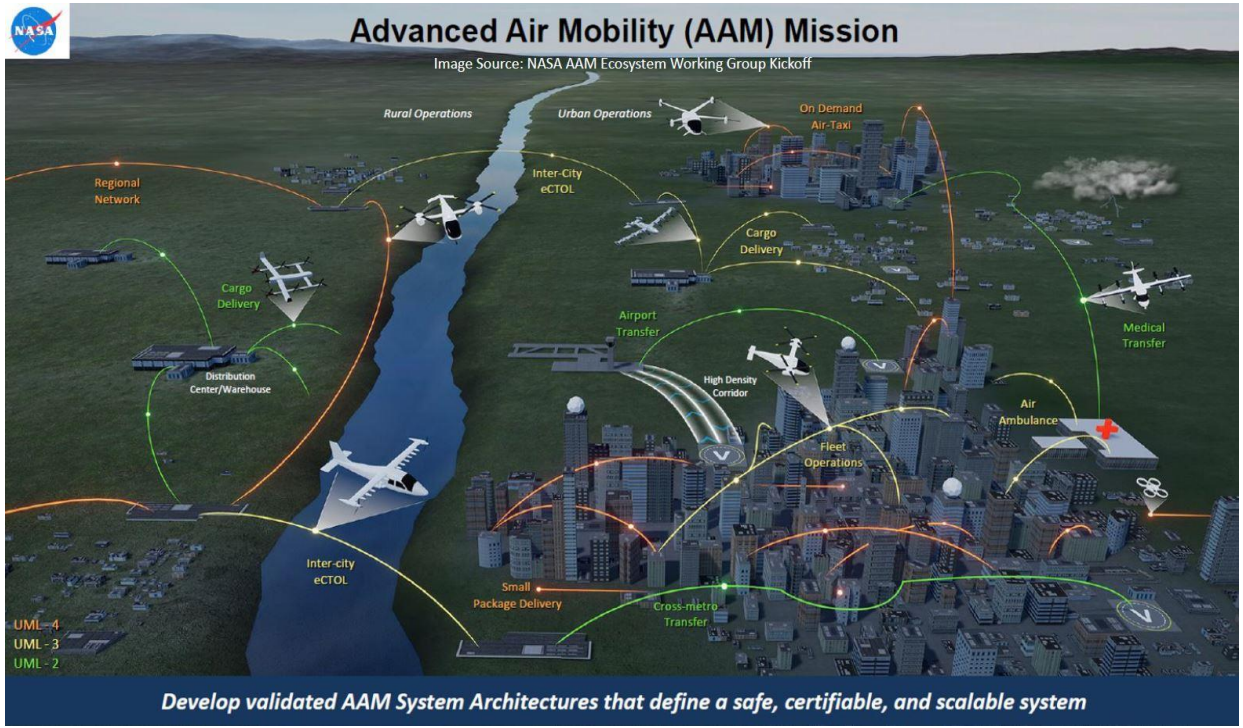
AAM Research Framework

UAM Vision: Revolutionise mobility around metropolitan areas by enabling a safe, efficient, convenient, affordable, and accessible air transportation system



AAM/UAM Missions

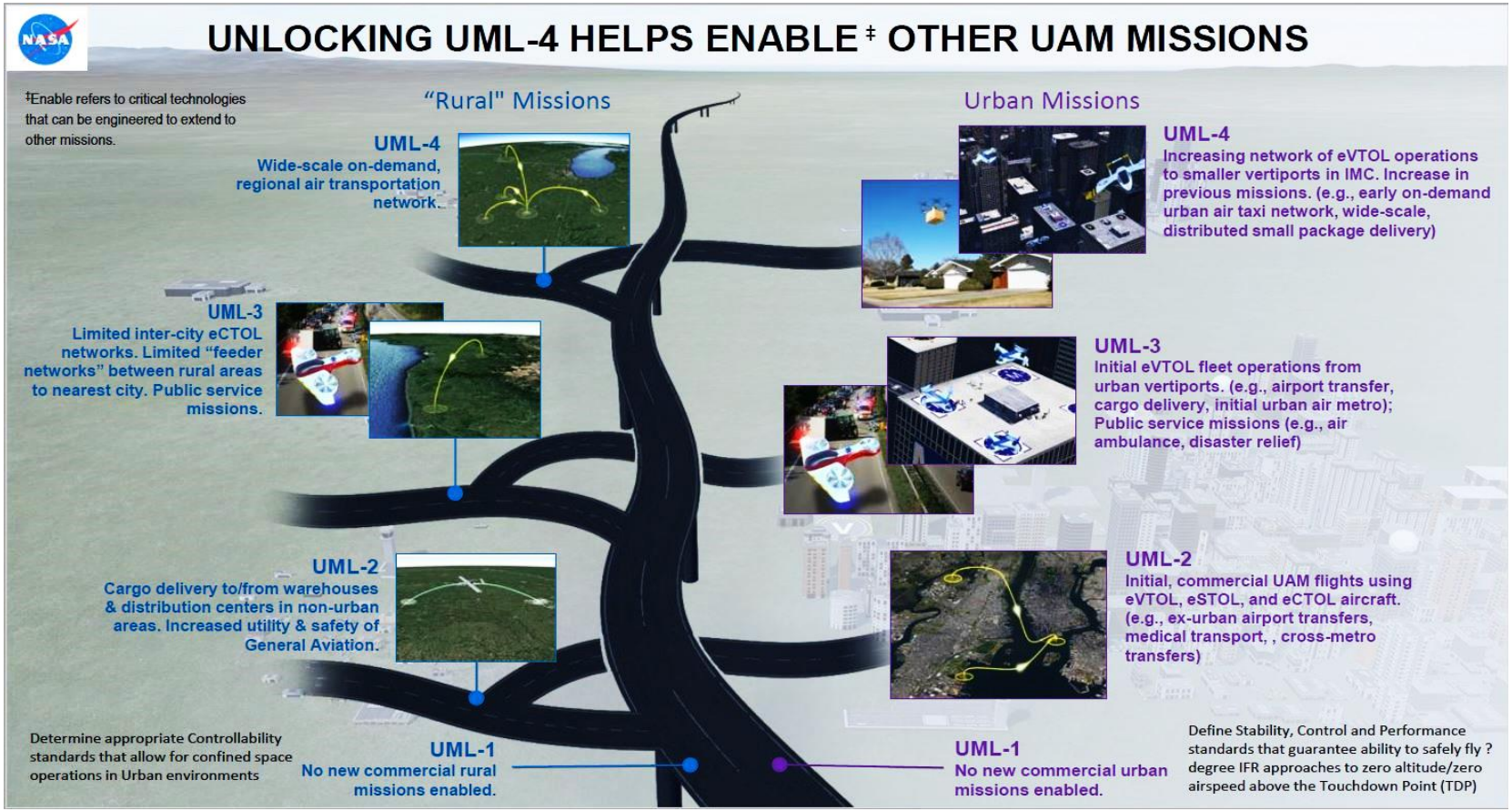
- Includes rural and urban applications
  - Cargo transport, aerial work, etc.
  - eVTOL, sUAS, hybrid-electric etc.
  - UAM as a challenging use-case
- Enabled by electrification and scaled through automation
- Does not include:
  - Supersonic or hypersonic
  - Existing hub-and-spoke



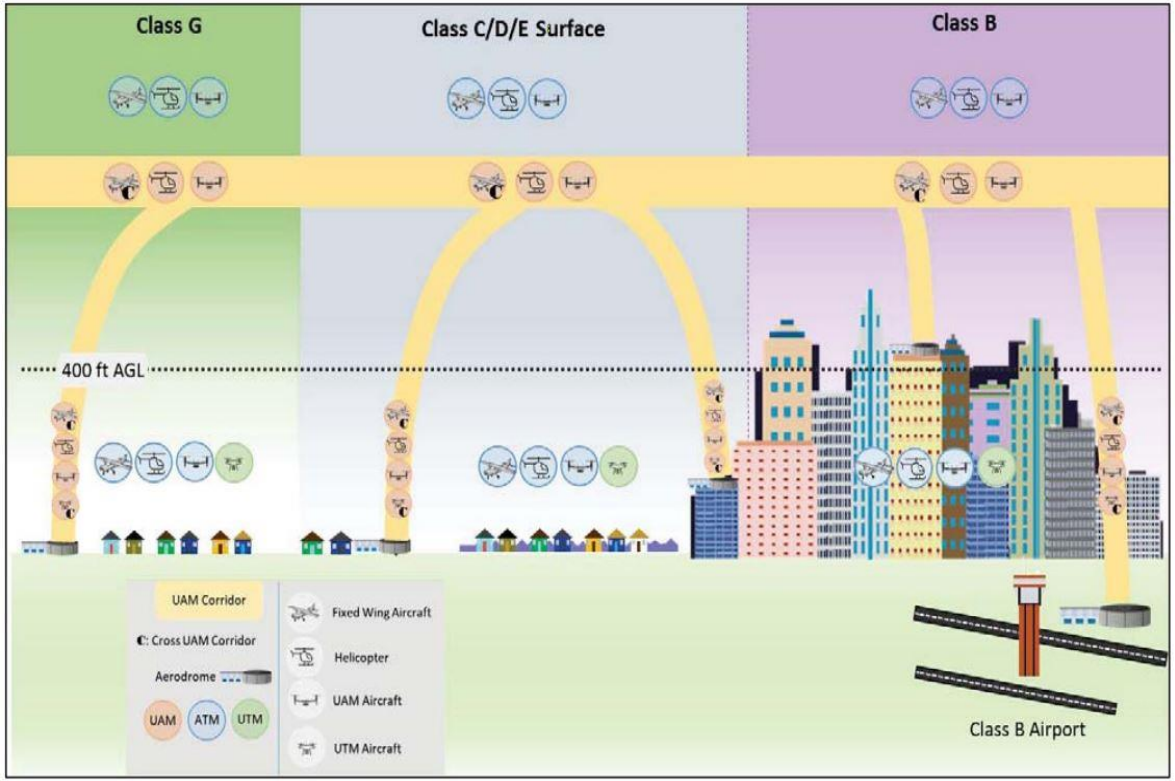
NASA UAM Maturity Levels (UML)

		Vehicles	Airspace	Community
INITIAL STATE	UML-1	**Late-Stage Certification Testing and Operational Demonstrations in Limited Environments** Aircraft certification testing and operational evaluations with conforming prototypes; procedural and technology innovation supporting future airspace operations (e.g. UTM-inspired); community/market demonstrations and data collection		
	UML-2	**Low Density and Complexity Commercial Operations with Assistive Automation** Type certified aircraft; initial Part 135 operation approvals; limited markets with favorable weather and regulation; small UAM network serving urban periphery; UTM Construct and UAM routes supporting self-managed operations through controlled airspace		
INTERMEDIATE STATE	UML-3	**Low Density, Medium Complexity Operations with Comprehensive Safety Assurance Automation** Operations include urban core; operational validation of advanced airspace operations and management including UTM inspired ATM, CNSI, C^2, and automation for scalable, weather-tolerant operations; few high-capacity vertiports; noise compatible with urban soundscape; model-local regulations		
	UML-4	**Medium Density and Complexity Operations with Collaborative and Responsible Automated Systems** 100s of simultaneous operations; expanded networks including closely-spaced high throughput vertiports; many UTM inspired ATM services available, simplified vehicle operations for credit; low-visibility operations		
MATURE STATE	UML-5	**High Density and Complexity Operations with Highly-Integrated Automated Networks** 1,000s of simultaneous operations; large-scale, highly-distributed networks; high-density UTM inspired ATM; autonomous aircraft and remote, M:N fleet management; high-weather tolerance including icing; high-volume manufacturing		
	UML-6	**Ubiquitous UAM Operations with System-Wide Automated Optimization** 10,000s of simultaneous operations (capacity limited by physical infrastructure); ad hoc landing sites; noise compatible with suburban/rural operations; private ownership & operation models enabled; societal expectation		

AAM/UAM Missions



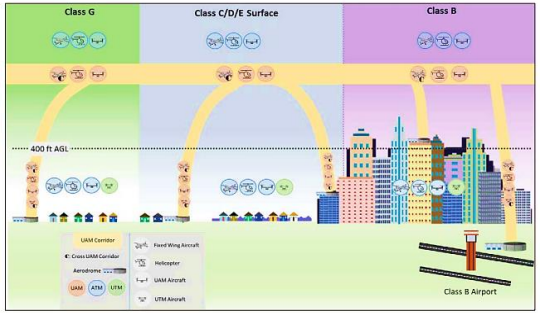
Evolutionary systems for UTM and AAM

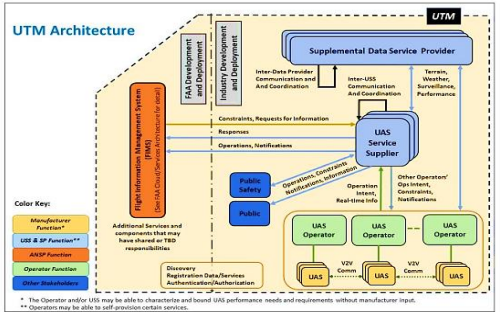


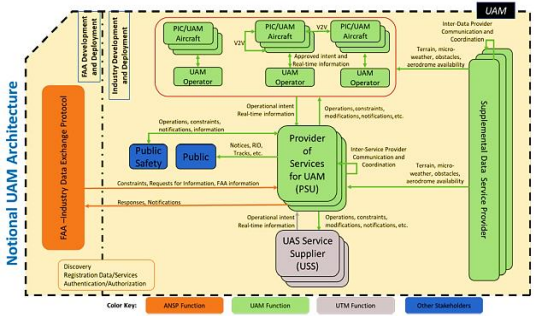
- Integrated CNS (ICNS) for the large amount of data/information that needs to be exchanged
- On-board vehicle situational awareness and sensors required
- Vertiport infrastructure
- Automation relationship to scalability
- Time-Based Flow Management
  - PBN and TBO
  - Sequencing and Spacing
  - Congestion Management
- Moving towards **PBO**
- Health/performance monitory systems (safety-critical)
- Microclimate sensor requirements

Present R&D Challenges

- Develop a CONOPS for Low-Altitude Airspace Management (LAAM) encapsulating UTM and emerging AAM requirements, which clearly specifies the human role for various levels of automation
- Develop new DSS functionalities to enhance human-machine teaming. Current focus is on performance-based airspace modeling and dynamic airspace management
- Develop an integrated approach to Multi-Domain Traffic Management (long-term)







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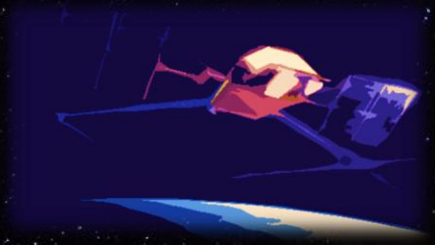
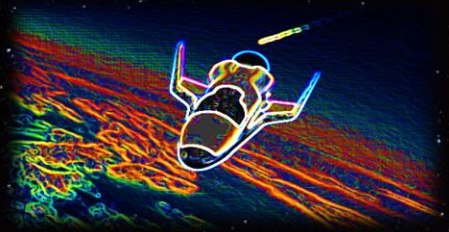
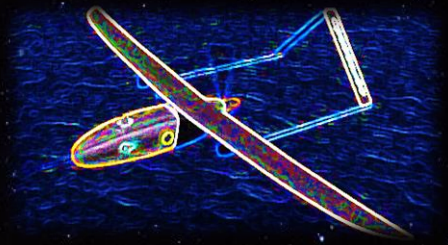


Thank you!

ASP





If you wish to discuss how you can contribute to the activities of the Avionics Systems Panel (ASP), please send an email to: roberto.sabatini@ku.ac.ae

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