



Integration of Structural Health Monitoring Systems into Unmanned Aerial
Systems – Challenges and Opportunities

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Stanford 13 September 2011

Agenda

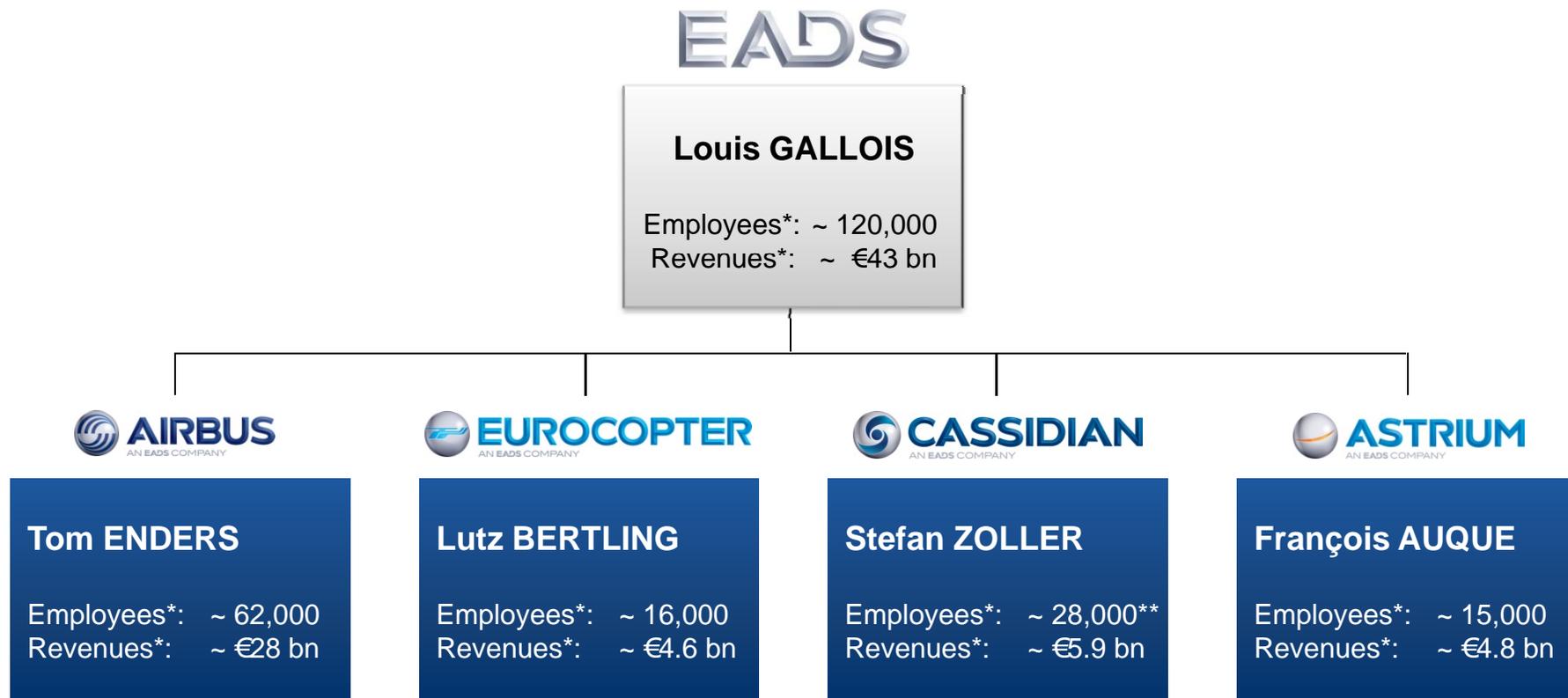


- Introduction
 - Unmanned Systems Trends and Opportunities
- Challenges
 - Reduce Through Life Cost
 - V&V Framework for Certification of ISHM / CBM
- SHM Integration and Certification Status for unmanned Systems

CASSIDIAN

One of the four pillars of EADS

Standing alongside Airbus, Astrium and Eurocopter, we benefit from the **strength** and **synergies** of our co-Divisions, and contribute to the overall success of the Group



* in 2010

** with MBDA consolidated at 100%

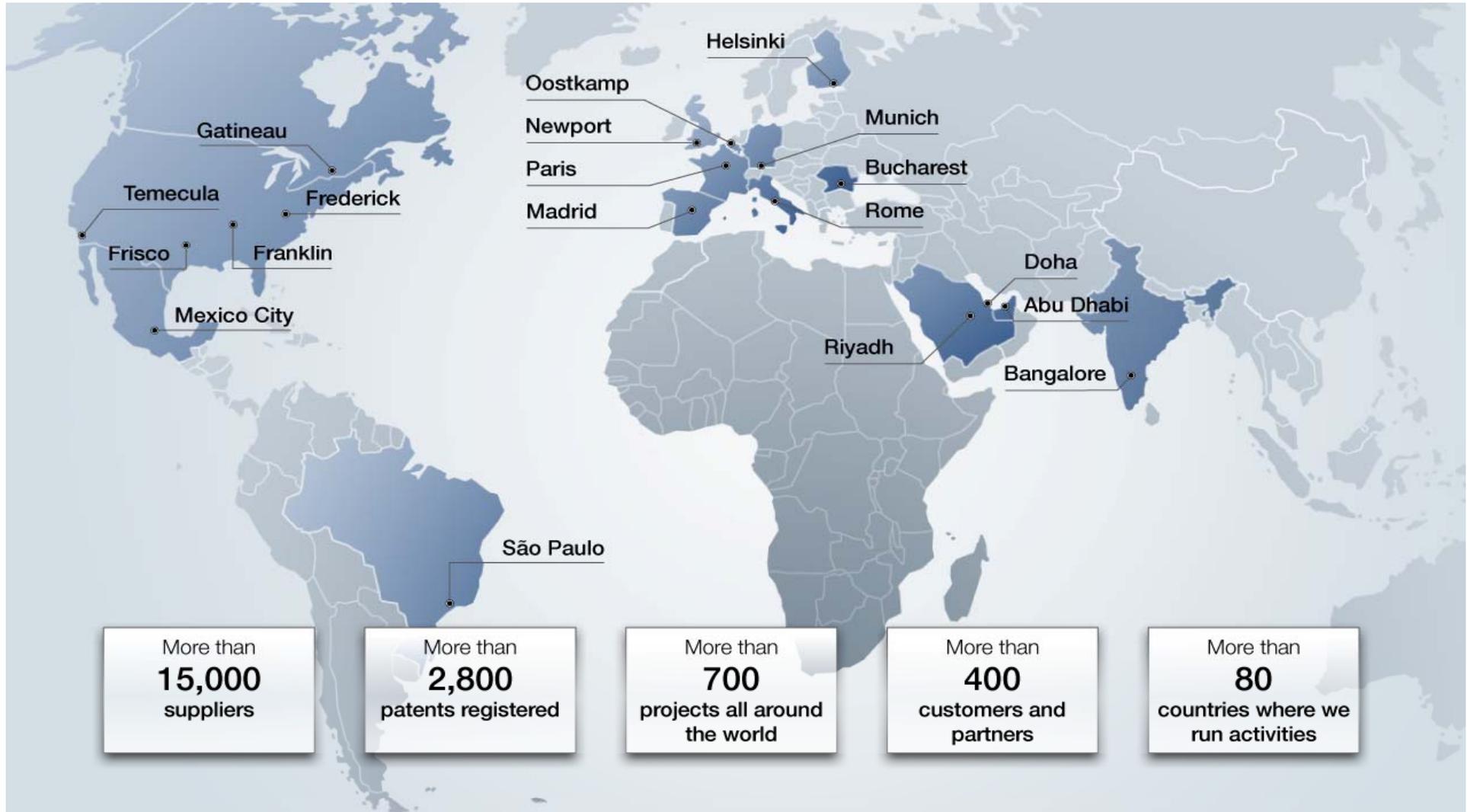
EADS Divisions

The Four Firm Walls EADS is built on



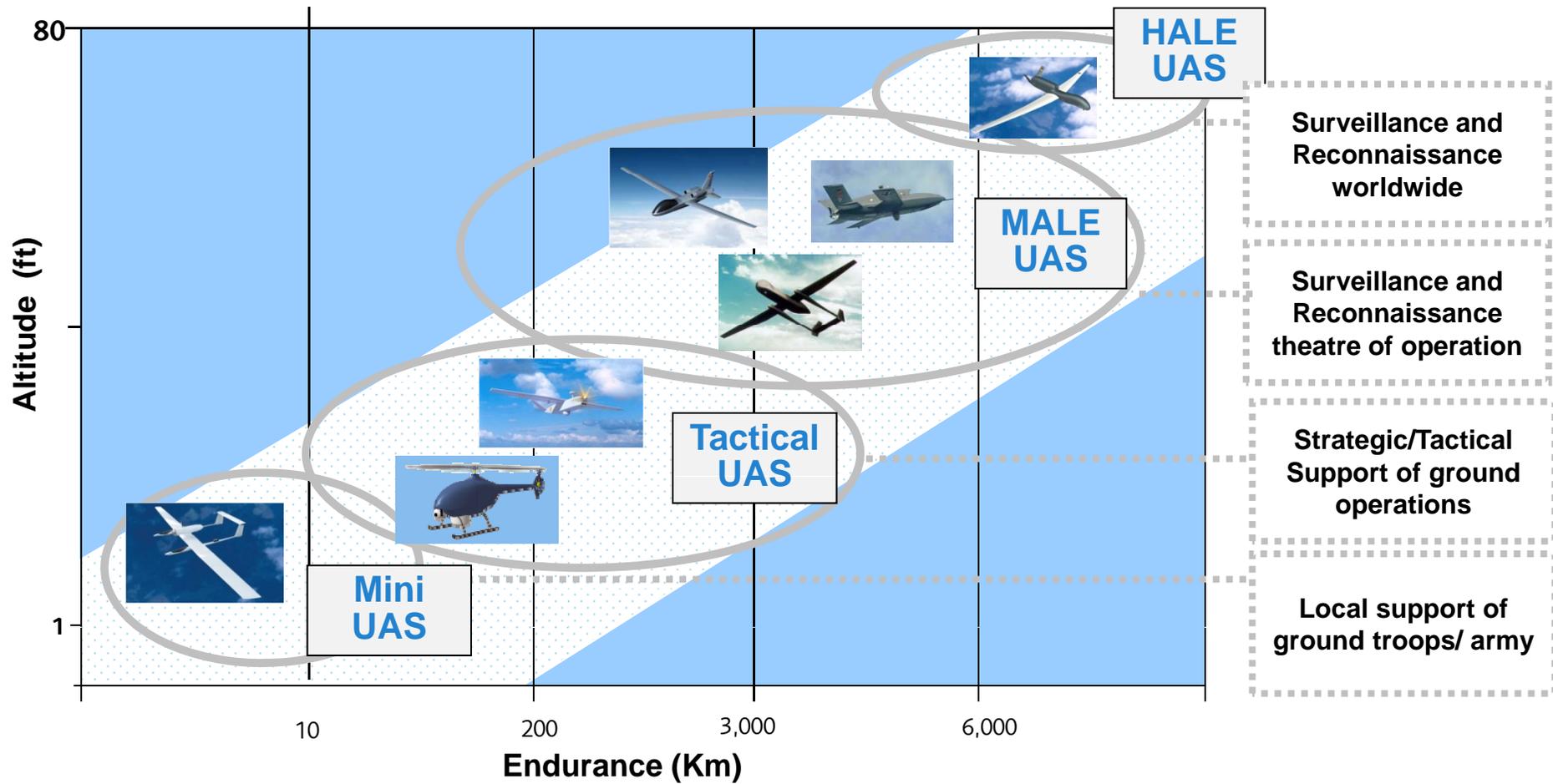
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Major Sites



30 years of UAS within EADS and EADS UAS Portfolio

HALE = High Altitude Long Endurance
MALE = Medium Altitude Long Endurance

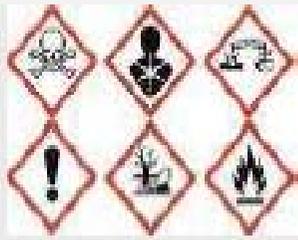


What makes Unmanned Systems so attractive?



**Long
Operating Time**

- Flight Endurance 24h / 48 h or even Days
- Optimum usage of flight profile



**Reduced
Human Risk**

- General reduced risk (no pilot on board)
- Application in risk areas (e.g. nuclear stations, fire fighting, vulcan , war zones etc.)

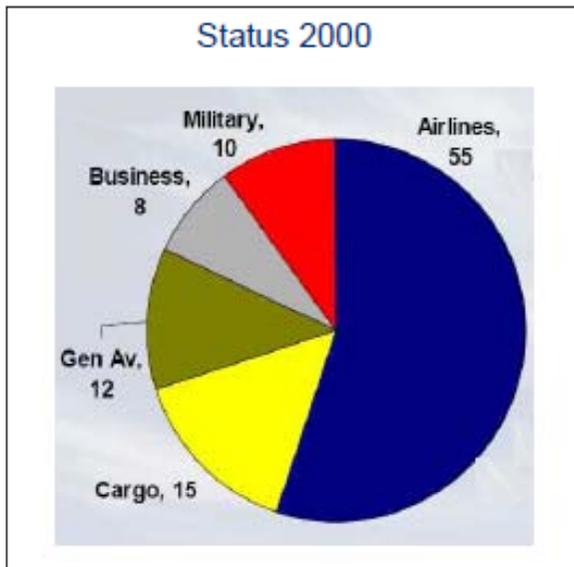


Cost

- Reduce Total Ownership Cost
- Reduction of Through Life Costs
- High potential of technology insertion

Distribution of Flight Systems over Market Segments

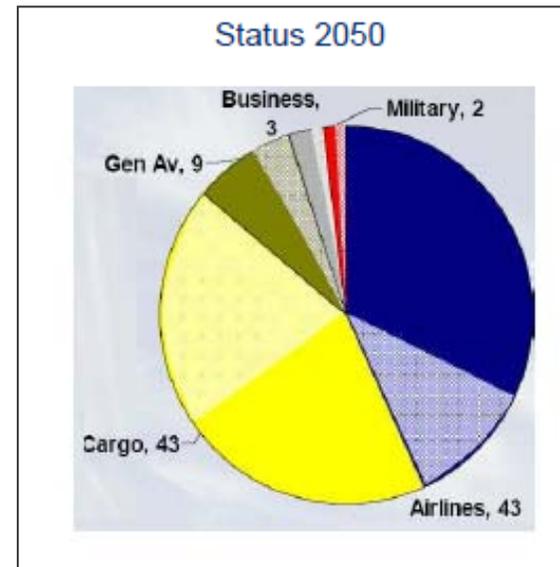
- Today



Contribution of UASs to Air Traffic
0.05 %

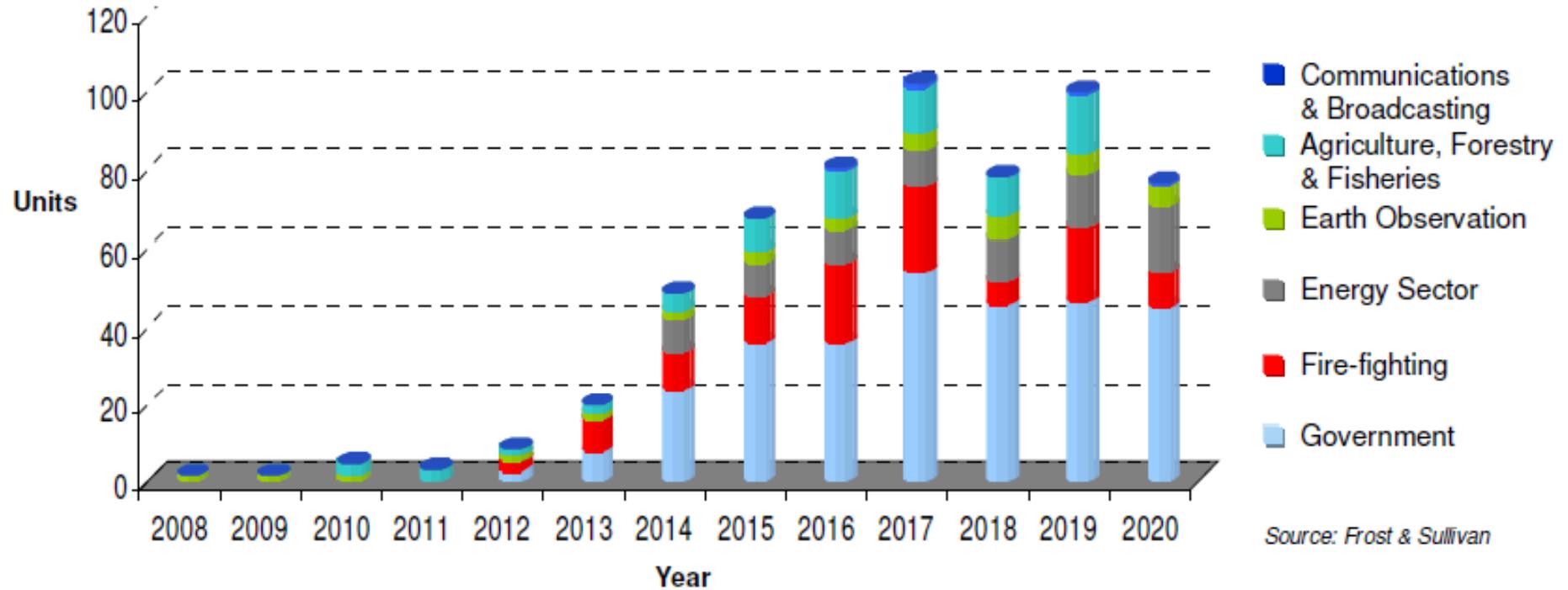
Source: FAA Forecast for FY2025

- Tomorrow



Contribution of UASs to Air Traffic
38 %

Civil- Commercial Application Forecast of UAS within Europe



The civilian market is restrained by the present absence of standards and regulations. As these are introduced the relevant segments will have the potential to grow rapidly

Source: Frost & Sullivan, Study analyzing the current activities in the field of UAS w/o micro- and mini UAS

The successful insertion of UAS within the civil airspace will face real challenges!

Technological Challenges

- Level of Autonomy in particular with increasing complexity of missions
- On-board Sensor Technologies
 - Sense & Avoid
 - **Situational & Condition Awareness**
- Automated Target Tracking and Identification
- Secured Communication

AT Regulations and Certifications

- Absence of regulations covering ATM and airworthiness
- Un-coordinated and fragmented approach [Industry and End Users) to cover UAS civil business development
- etc.

Through Life Cost

- Design for Service to ensure:
 - low cost / FH
 - predictable through life cost
 - provide affordable service solution approach (e.g. turn key solutions)

Social Acceptance

- Civilian: Concern – Suspicion
 - Perceived public safety risks
 - Suspicion concerning privacy [surveillance society]
- Public acceptance will follow with the recognition of the benefits that UAS can bring to the society.

Key Success Factors for UAS Civil Application



NextGEN (U.S.) SESAR (EU)

Certification

- Insertion into Air Traffic Management
- Flying in non segregated airspace



Cost

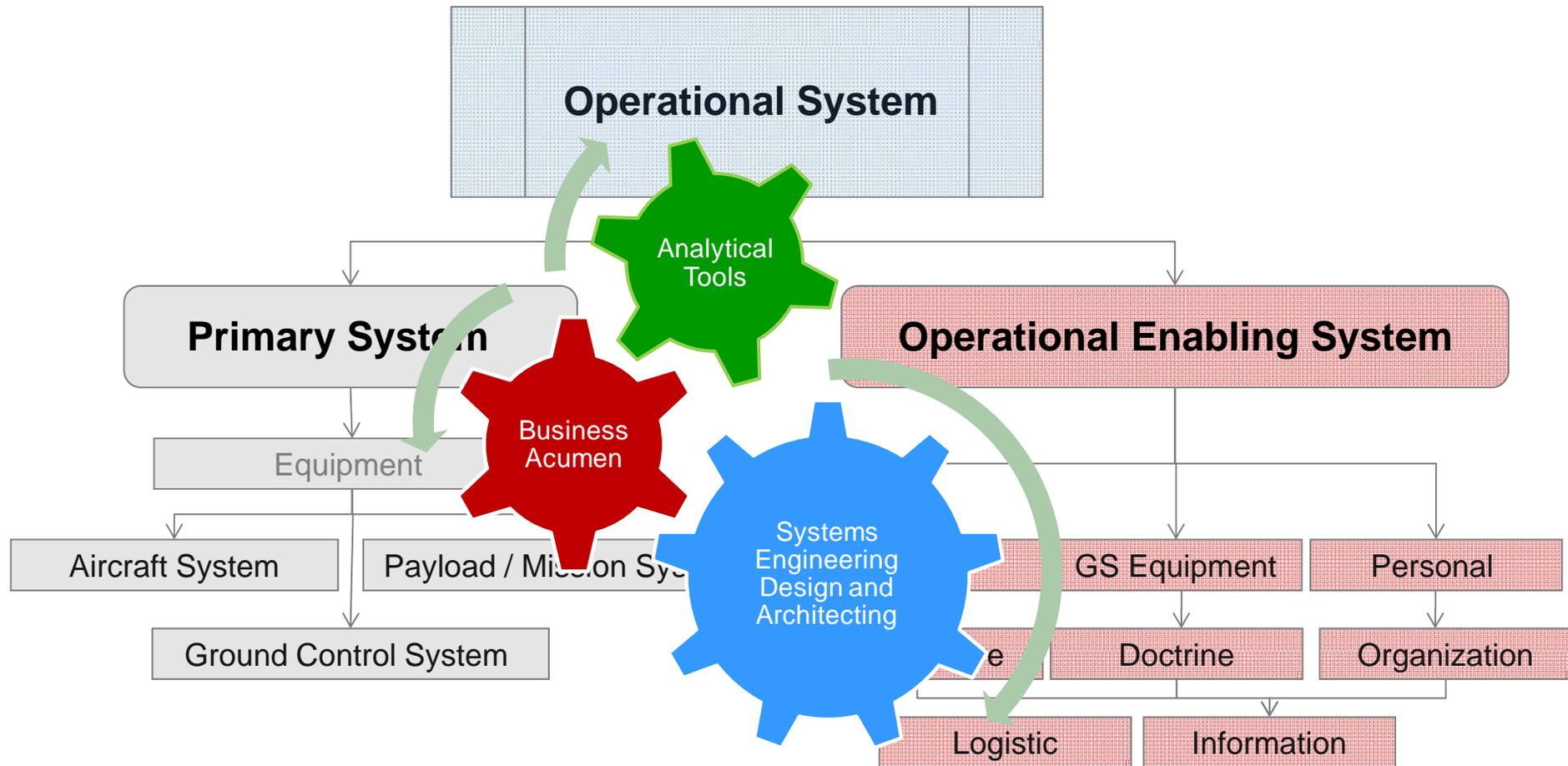
- Total Cost of Ownership
- Through Life Support Cost
- Cost per Flying Hours

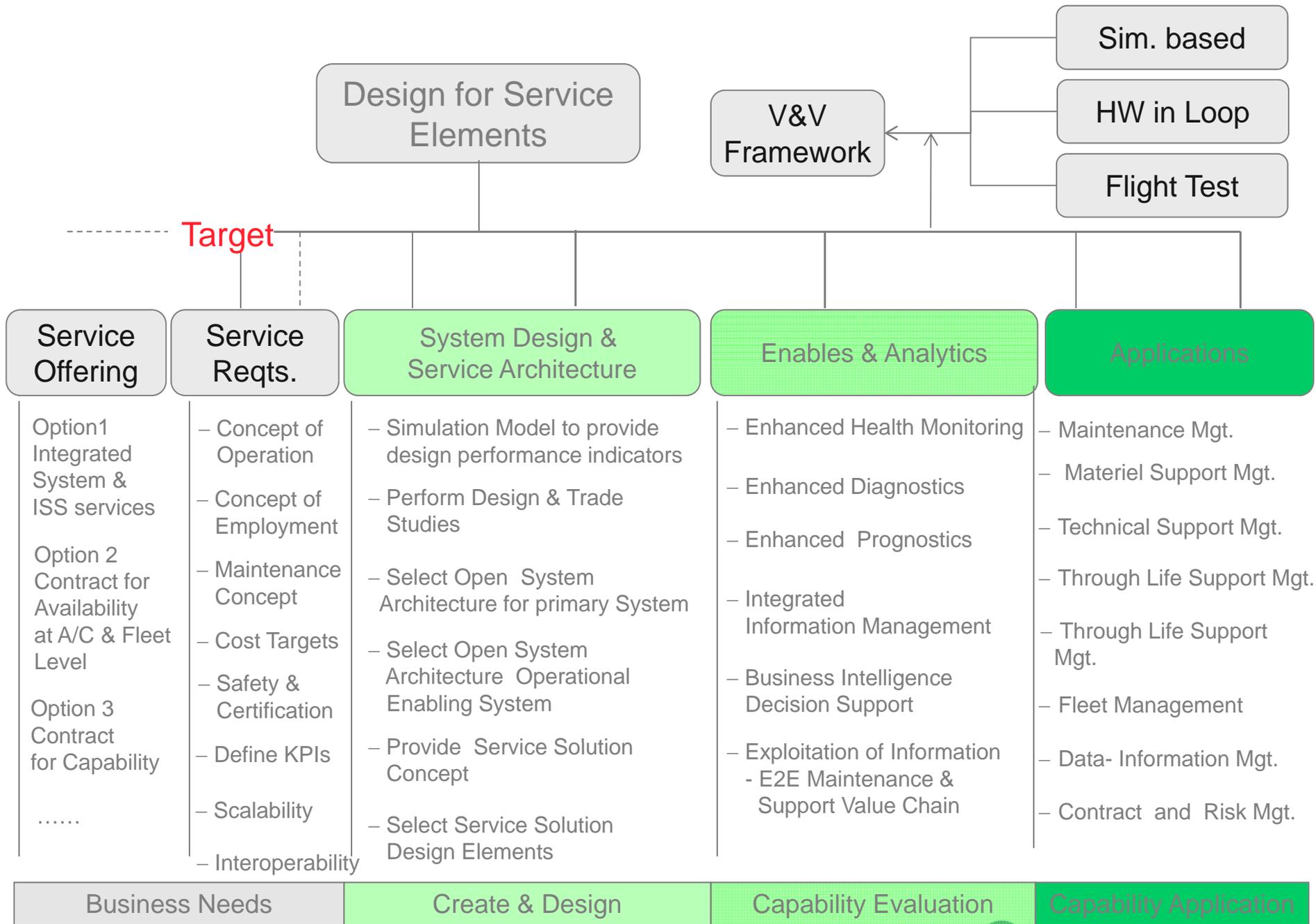
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Design for Service Approach





Relationship Service Requirements and Design Requirements

- Operational Performance Parameter (Top Level Requirements] Contract)

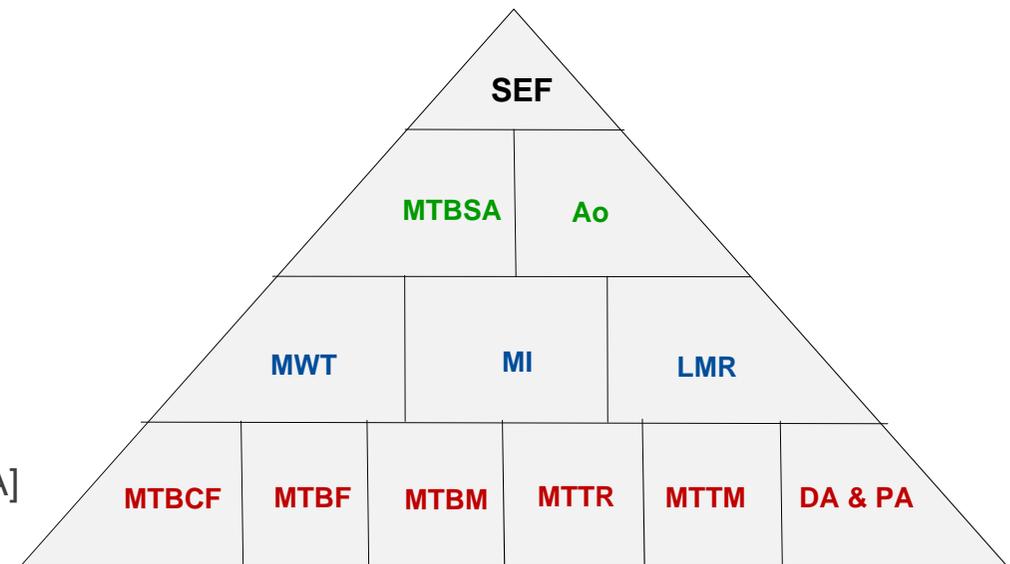
- Operational Availability [A0]
- Mission Capability Rate [MCR]
- System Effectiveness [SEF]

- Service Performance Parameter (Logistics / Service Effort)

- Logistic Maintenance Ratio [LMR]
- Maintenance Index [MI]
- Mean Waiting Time [MWT]
- Mean Time between System Aboard [MTBSA]
- Mean Logistic Delay Time [MLDT]

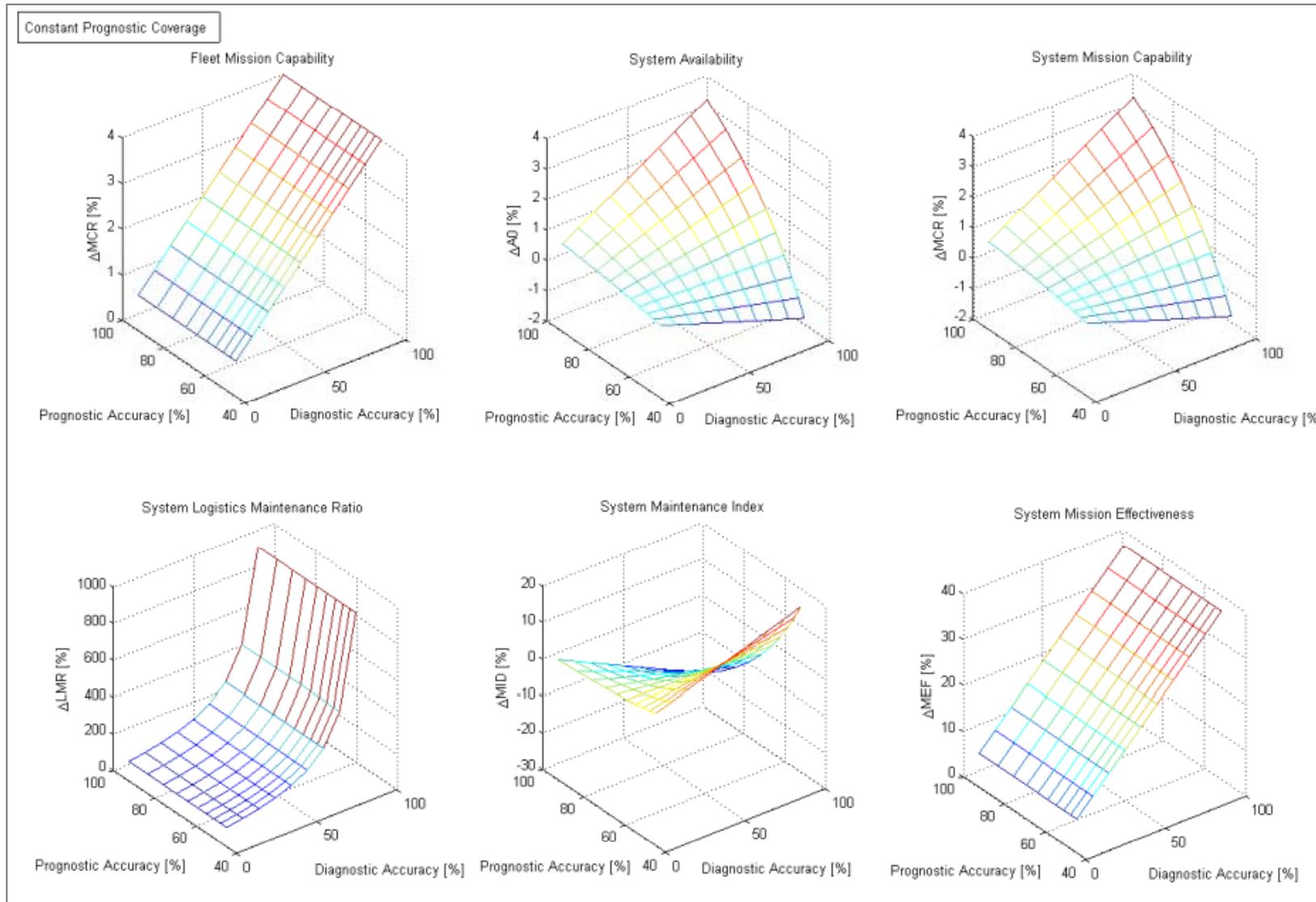
- Design Parameter (L2 / L3 Design)

- Mean Time between Critical Failure [MTBCF]
- Mean Time between Failure [MTBF]
- Mean Time between Maintenance [MTBM]
- Mean Time to Repair [MTTR]
- Turn around Time [TAT]
- Diagnostic (Prognostic) Capabilities



- Operational Performance Parameter
- Service Performance Parameter
- Design Parameter

Diagnostic and Prognostic Requirements as a Function of Service Performance



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Survey of Certification Standards related to ISHM

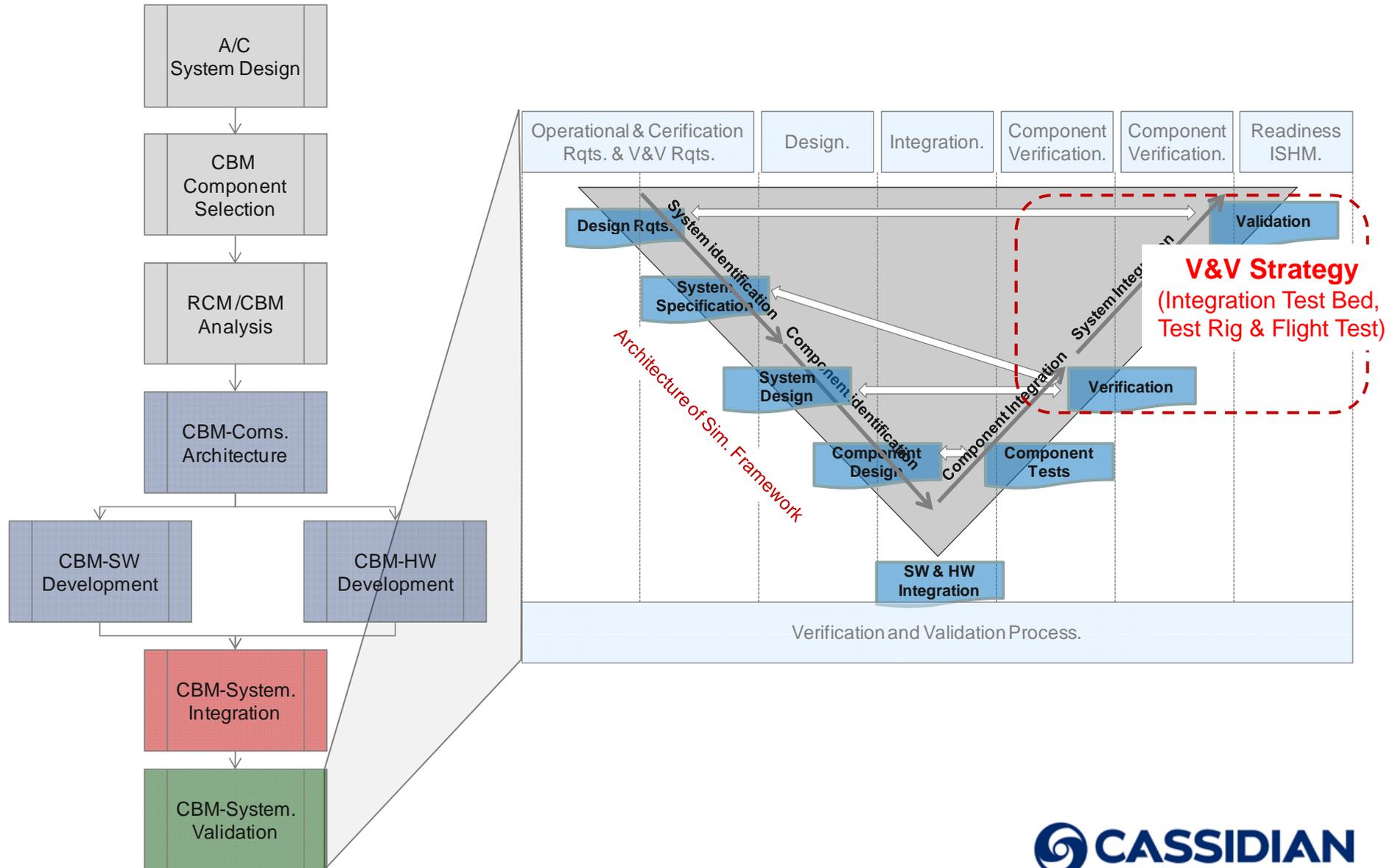
- **V & V Guideline**

- V&V^Strategy of CBM Maintenance Credit by Vertical Lift Consortium Industry Team (May, 2011)
- Certification of HUMS as per FAA's Advisory Circular AC 29-2C MG-15

- **Guideline for complete life cycle**

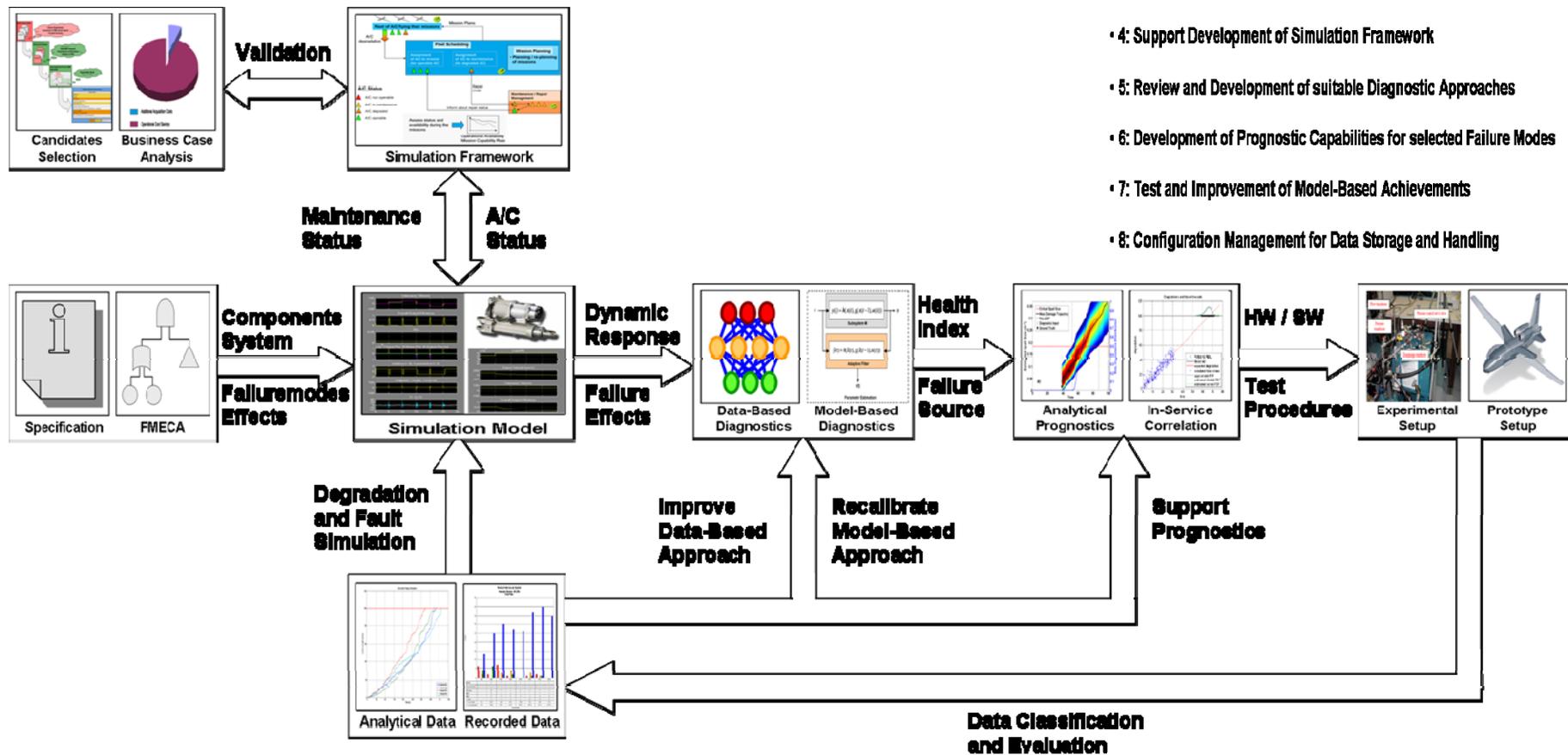
- Aeronautical Design Standard Handbook for Condition Based Management for US Army Aircraft (ADS-79B, 16 January 2011)
 - CBM Development for Legacy A/C
 - CBM Development for new acquisition

System Design of Simulation based V&V CBM / ISHM Framework



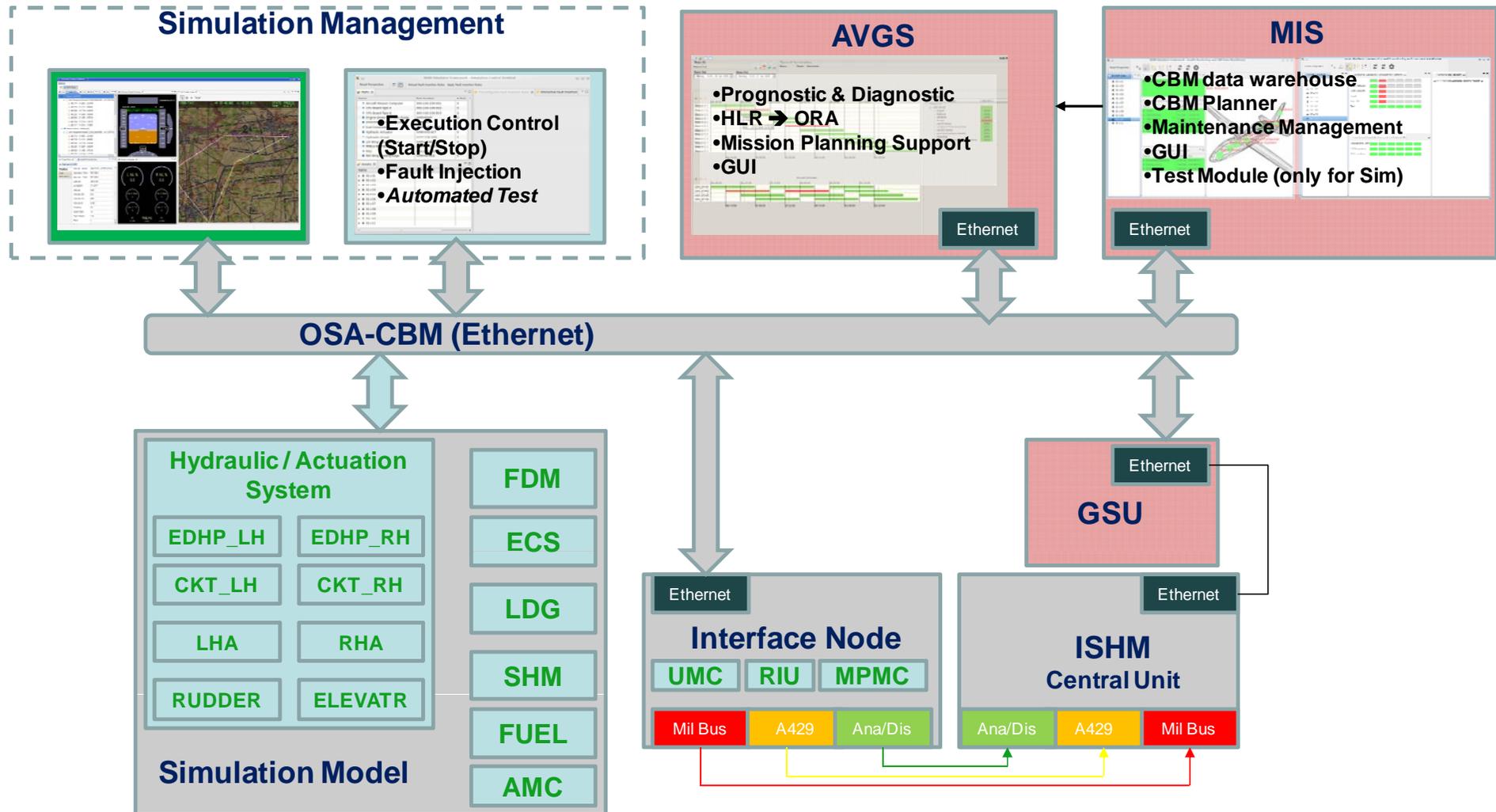
Diagnostic and Prognostic Development

- 1: Candidates Selection and Business Case Evaluation
- 2: Review of Specification and FMECA for selected Candidates
- 3: Development of Simulation Model
- 4: Support Development of Simulation Framework
- 5: Review and Development of suitable Diagnostic Approaches
- 6: Development of Prognostic Capabilities for selected Failure Modes
- 7: Test and Improvement of Model-Based Achievements
- 8: Configuration Management for Data Storage and Handling



System Design of Simulation based V&V ISHM Framework

ISHM V&V Simulation Framework



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Steps to Certification

- Certification involves processes to obtain the approval of the Regulatory Authority that the applicable airworthiness requirements and operating regulations are met.
- Regulatory Authorities

examples



MINISTRY OF DEFENCE

civil

military

- For UASs, the regulation/standards are:
 - Airworthiness: STANAG 4671 Edition 1 (derived from manned aircraft standards)
 - Integration into airspace: Eurocontrol spec 0102
- Qualification is the process to validate and verify that a product (an SHM system for example) complies with a specified set of performance and airworthiness requirements.
- For UASs, commonly used qualification guidelines are:
 - Structures: MIL-STD A-886x, DEF-STAN 00-970 Part1 Sec. 3, FAA AC 20-107A (Composites)
 - Systems: DO-254, DO-160D (hardware), DO-178B (software)

Safety Objectives according to STANAG 4671 ed 1

Relationship between probability and severity of failure condition effects

		Catastrophic	Hazardous	Major	Minor	No safety effect
Frequent	$> 10^{-3}/h$					
Probable	$< 10^{-3}/h$					
Remote	$< 10^{-4}/h$					
Extremely Remote	$< 10^{-5}/h$					
Extremely Improbable	$< 10^{-6}/h$					

	Unacceptable
	Acceptable

DESIGN ASSURANCE LEVEL (DAL) ACCORDING TO STANAG 4671 ed 1

DAL allocation for system and each portion of the system architecture		Degree of redundancy	
		Single failure/errors	Double failure/errors two or more independent/dissimilar portions
Failure Conditions Classification	Catastrophic	DAL B	DAL B for the system and, DAL C for each portion
	Hazardous	DAL C	DAL C for the system and, DAL D for each portion
	Major	DAL D	DAL D for the system and, DAL D for each portion
	Minor	DAL E	DAL E
	No Safety Effect	DAL E	

Once the criticality of a structure or system is determined, a Design Assurance Level (DAL) is assigned.

Certification Standards for On-Board critical System

TYPE OF IVHM SUB-SYSTEM	ASPECT OF CERTIFICATION	STANDARD / GUIDANCE
On-Board Critical System (A) -hosts direct action functions -fault-tolerance -redundancy management -closed-loop reconfigurable control	S/W Development	RTCA/DO 178B Level A or B
	H/W Development	RTCA DO-254 Level A or B
	System Engineering	MIL-STD-1629A (FMFCA) MIL-STD-2165 (Testability)
	V&V guidance of HUMS function	AC-29-2C, MG-15 (FAA's advisory circular)
	CBM guidance	ADS-79 B or C (US Army)
	Interface (OSA-CBM)	ISO-13374
	BIT/BITE Function	MIL-STD-1591
	Integrated Diagnostics	ARINC 604, 624-1
	Environmental	RTCA/DO 160D
	Integrity of Data	RTCA/DO 200A

SHM REQUIREMENTS

Applicability

- Composite Structures
- Metallic Structures

Functional

- Probability of Detection
- Minimum detectable Damage Size
- BITE Architecture
- Real Time onboard in flight measurements
- Diagnostic Accuracy
- Prognostics for Metallic Structure

HW / SW Interfaces

- Interface with existing data acquisition systems or onboard flight system
- Open System Architecture e.g. OSA CBM

continue see next page

Certification Standard for On-Board Non-critical System

TYPE OF IVHM SUB-SYSTEM	ASPECT OF CERTIFICATION	STANDARD / GUIDANCE
On-Board Non-Critical System (C) -hosts deferred action on-board functions -could be used for CBM automation or maintenance decision support. -the ultimate responsibility for critical decision is vested with the maintainer in ground	S/W Development	RTCA DO-178B Level C - D
	H/W Development	RTCA DO-254 Level C - D
	System Engineering	MIL-STD-1629A (FMECA) MIL-STD-2165 (Testability)
	V&V guidance of HUMS function	AC-29-2C, MG-15 (FAA's advisory circular)
	CBM guidance	ADS-79 B or C (US Army)
	Interface (OSA-CBM)	ISO-13374
	BIT/BITE Function	MIL-STD-1591
	Integrated Diagnostics	ARINC 604, 624-1
	Environmental	RTCA DO-160D
	Integrity of Data	RTCA/DO 200A

SHM REQUIREMENTS

[continue]

Environmental (In Flight)

- Temperature
- Vibration
- Electro Magnetic Compatibility
- Humidity; Water Proof
- Operational Shock Testing

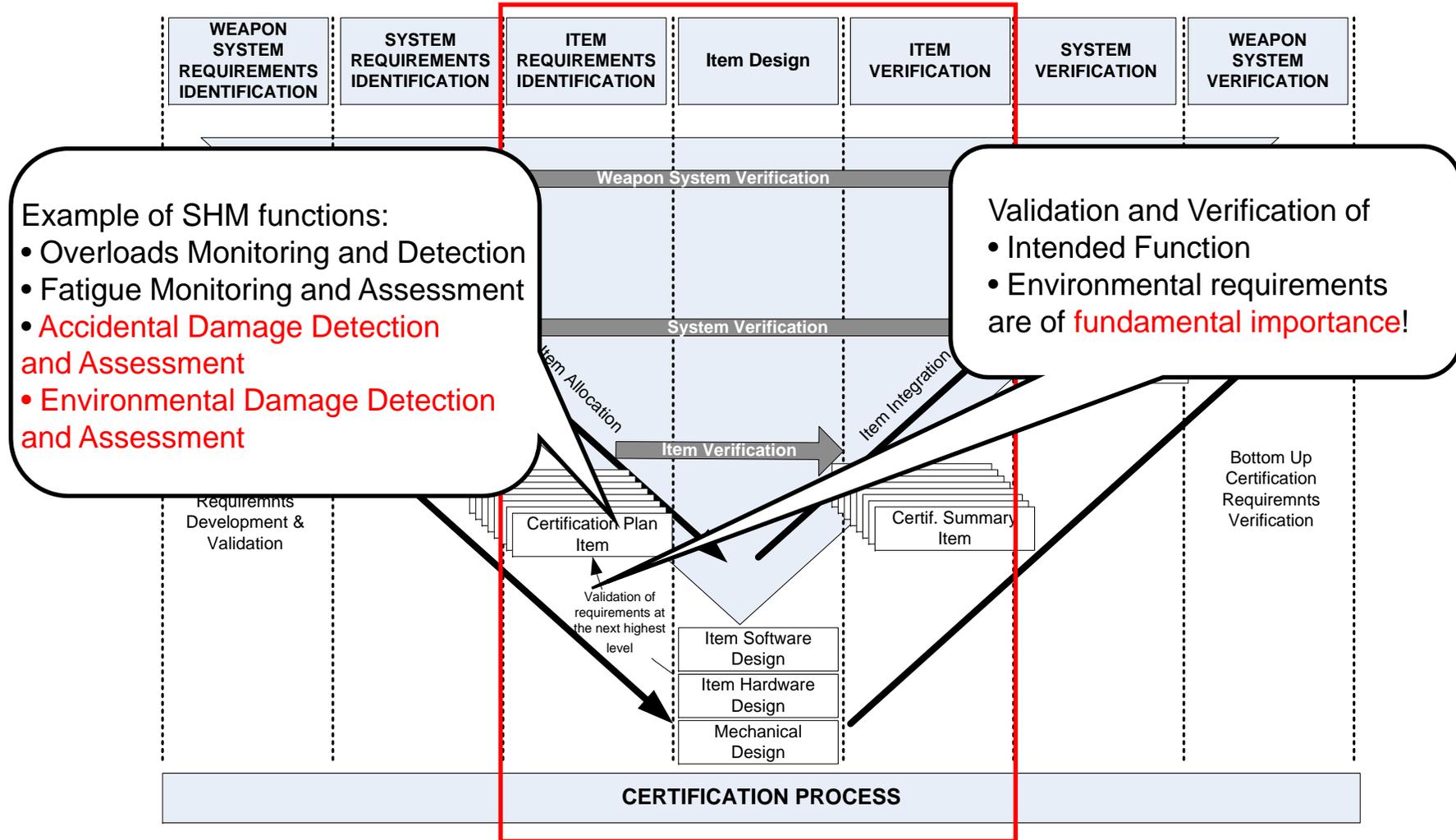
Installation

- Sensor Installation
- Surface Cleaning
- Adhesive & Sensor Application
- Sensor Protection
- Mechanical and Electrical Installation

Human Machine Interface

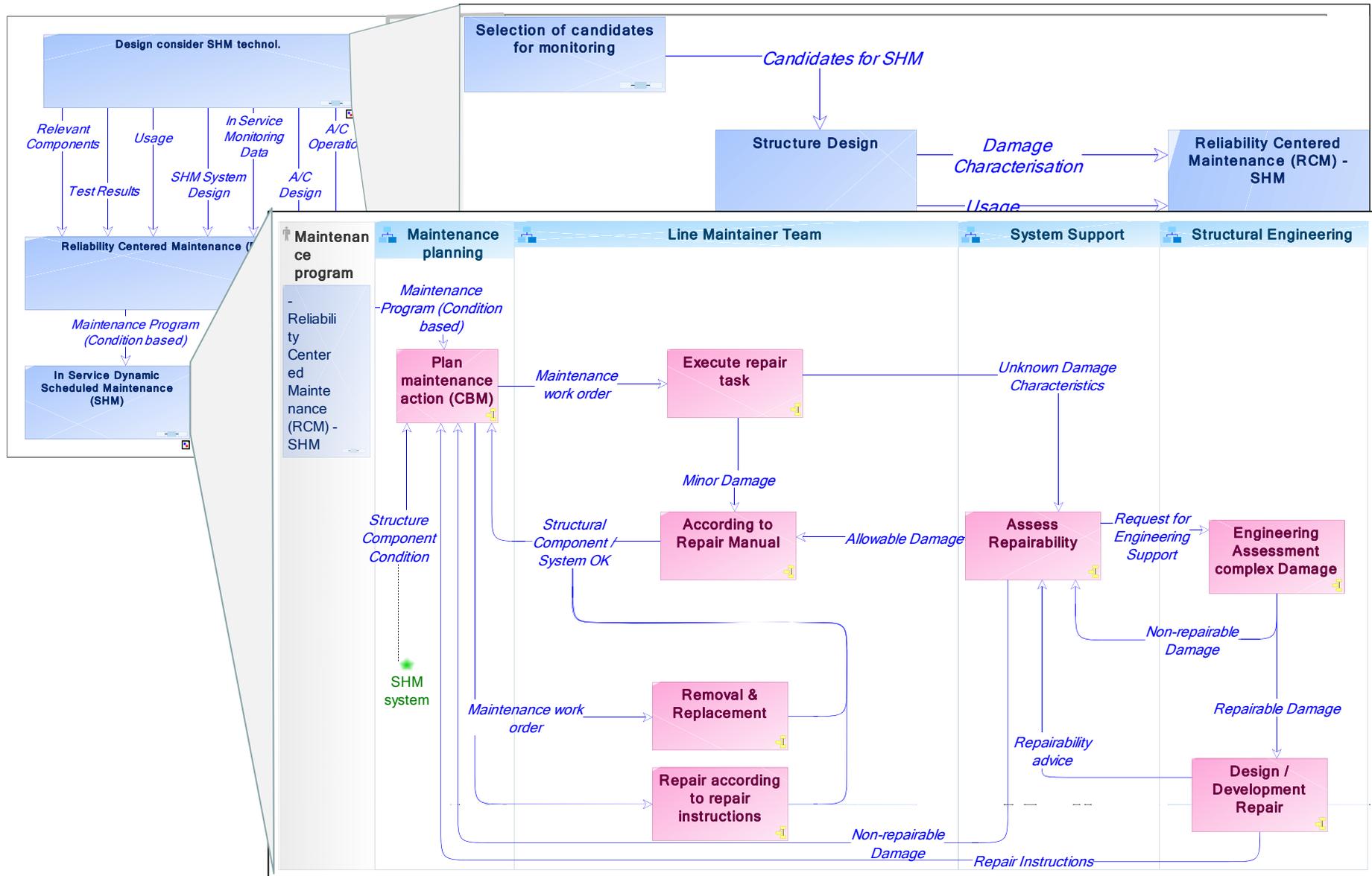
- Display, Interpretation etc.
- Information Dissemination
- Traceability

SHM Certification Process



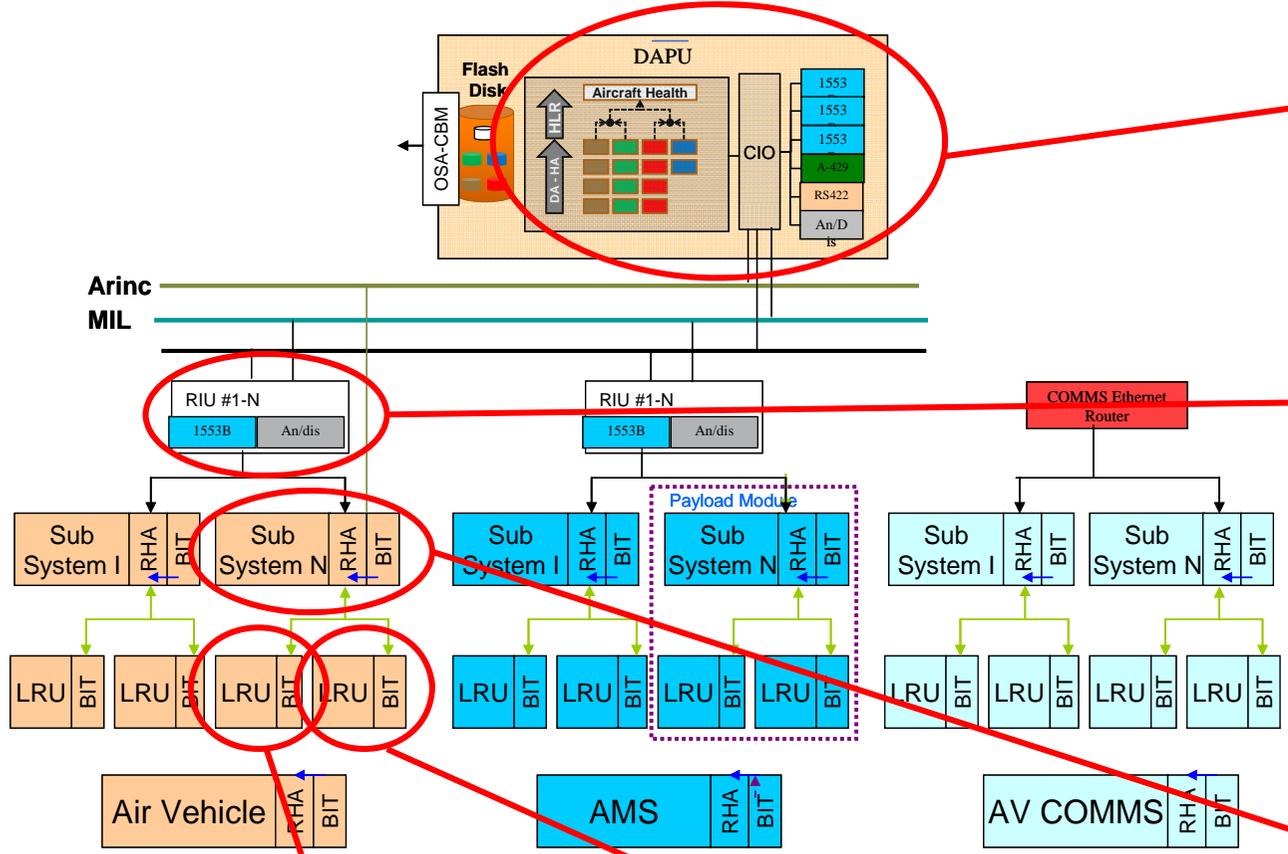
SHM Certification Process

Example – to derive and understand SHM Certification Rqts. 1/3



SHM Function within ISHM

containing from Health Assessment upwards



Damage size vs. Criticality vs. Safety?

Conclusions

- At Cassidian, a Design for Service approach has been developed to provide more confidence and creditability in the through life support cost of UASs.
- Within this framework, UAS SHM systems play an important role because
 - SHM reduces direct operating and life cycle costs
 - SHM systems contribute to the fulfilment of aircraft airworthiness requirements
- The end effect is to reduce UAS mishap rates and supporting the integration of UASs into national and international airspace outside of restricted areas (CAT 3).
- Qualification of an SHM System for Certification is only possible with mature SHM technologies