CASSIDIAN
AN EADS COMPANY
BAE SYSTEMS
HAHN Spring Ltd

SAE Aerospace
An SAE International Group

Proceedings of the 9th International Workshop on Structural Health Monitoring 2013

The Need for Guidance on Integrating SHM within Military Aircraft Systems

Matthias Buderath
Jim McFeat
Hesham Azzam

CASSIDIAN
AN EADS COMPANY
BAE SYSTEMS
HAHN Spring Ltd

CASSIDIAN
AN EADS COMPANY
BAE SYSTEMS
HAHN Spring Ltd

SAE Aerospace
An SAE International Group

- Background Information
- The G-11 AISC Military Aircraft Working Group
- Motivations for Military SHM Guidelines
- Status of Military Guidebook Development
- Competencies and skills required for MAWG
- Concluding Remarks

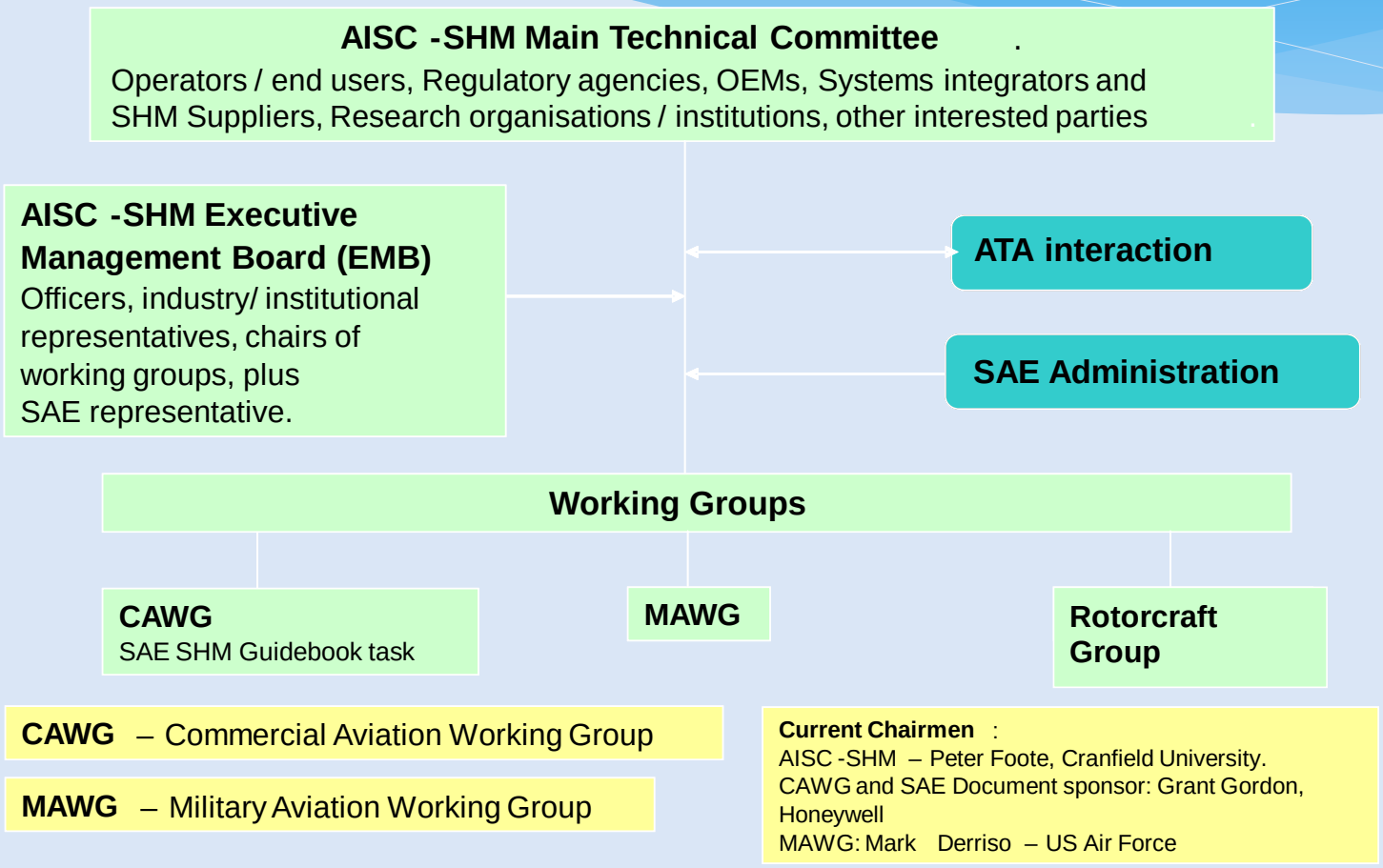
Background Information 1/2
Vision and Motivation of AISC-SHM

The AISC – SHM is an international team comprising industry, government and academic participants with a collective vision to efficiently and effectively implement structural health monitoring for a wide variety of commercial, military and rotorcraft aerospace applications through the development of standards, procedures, processes and guidelines for implementation and certification of the technologies.

The AISC-SHM operates as a Technical Committee within SAE International‘s Aerospace Standards Program (G-11 SHM)

Background Information 2/2

ASIC – SHM Aerospace Industry Steering Committee for Structural Health Monitoring - Committee structure



The committee is also known as G-11 SHM within the SAE International Aerospace Division

CASSIDIAN
AN EADS COMPANY
BAE SYSTEMS
HAHN Spring Ltd

SAE Aerospace
An SAE International Group

- Background Information
- The G-11 AISC Military Aircraft Working Group
- Motivations for Military SHM Guidelines
- Status of Military Guidebook Development
- Competencies and skills required for MAWG
- Concluding Remarks

G-11 AISC MAWG Main Contributors

BAE SYSTEMS

BOEING

HAHN Spring Ltd

EMBRAER

TU Delft

Cranfield UNIVERSITY

Honeywell

UTC Aerospace Systems

Military Aviation Authority
MAA

Further military and industrial organizations have expressed interest and will join MAWG in the near future.

The committee is also known as G-11 SHM within the SAE International Aerospace Division

The G-11 AISC Military Aircraft Working Group

The Goal of MAWG

Objective:

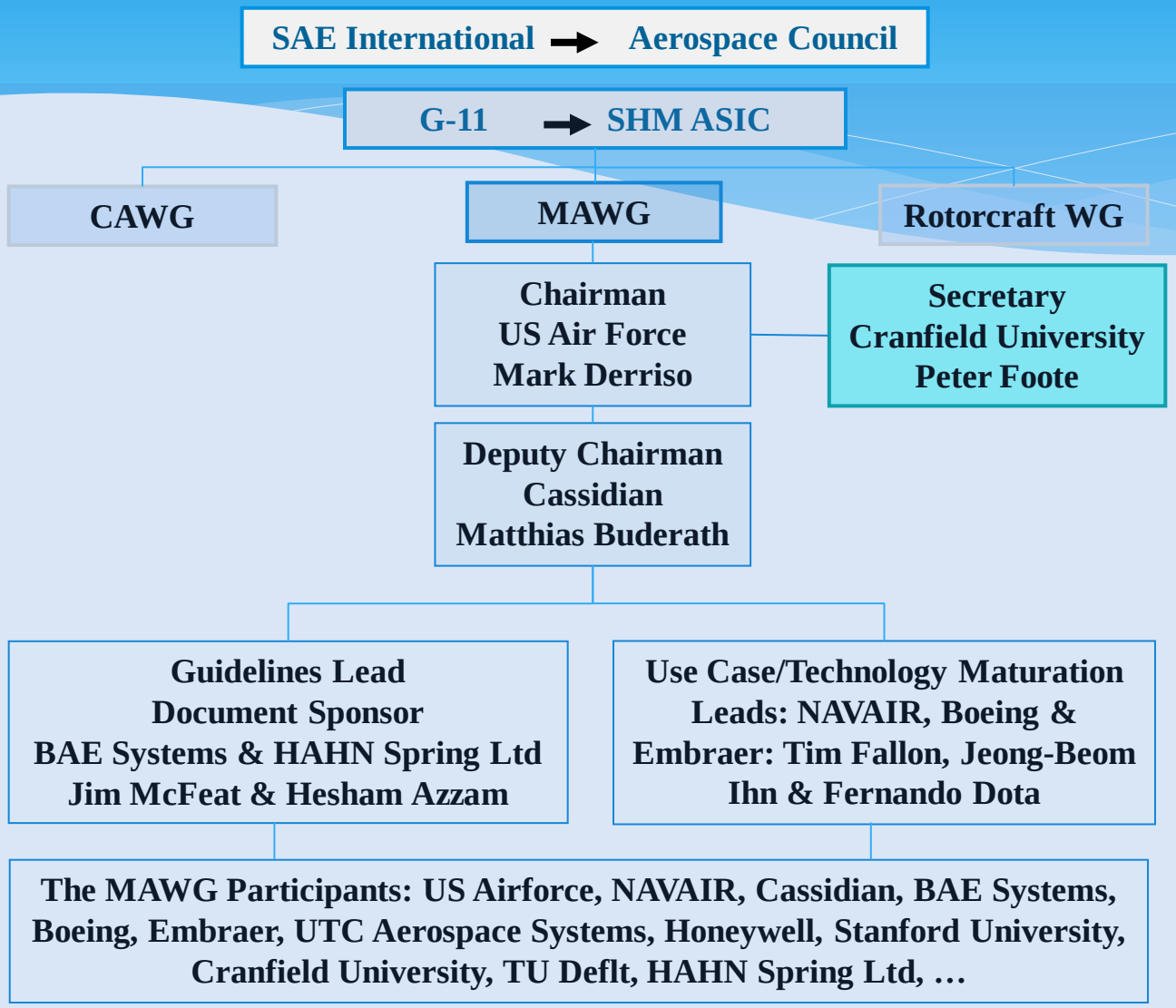
- **to establish a standard framework and process to integrate SHM technologies into the current military aircraft management process.**
- **to provide the end users with guidance for SHM system design, installation, certification and exploitation within innovative maintenance and A/C operation concepts**

Scope of Work:

- **Reviewing military documents applicable to SHM**
- **Evaluating the relevance of SHM to military requirements and support engineering processes**
- **Presenting methods to integrate SHM with military maintenance processes: including Logistic Support**
- **Evaluation of requirements to integrate SHM into Health Management System including interface to Mission and Flight Management System Maintenance, Mission and Flight Systems**

The G-11 AISC Military Aircraft Working Group

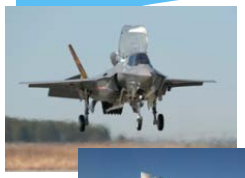
The Organization of MAWG



- Background Information
- The G-11 AISC Military Aircraft Working Group
- Motivations for Military SHM Guidelines
- Status of Military Guidebook Development
- Competencies and skills required for MAWG
- Concluding Remarks

Motivations for Military SHM Guidelines 1/4

Trends in Military Air Systems



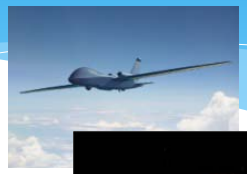
Aircraft / Fleet Availability

- Condition Based Maintenance
- Remaining useful life quantification

Mission Capability

- Maximized vehicle performance based on individual response to environment => no pre-determined inspection interval
- Improved systems fault detection, isolation and accommodation

Short Term



Mission Capability

- System availability, feeding mission planning systems in real-time with structural health status
- Decision Engine to provide assessment of functional availability
- Improved fault detection and isolation through aggregation of diagnostic at aircraft level.
- Maximized system availability based on complete system health awareness and maintenance management

MidTerm

Mission Capability

- Enabling autonomous mission re-planning based on assessment of he impact on mission capability

Self Reliant Platform

- Contingency Management – environment awareness
- Interaction with flight management system

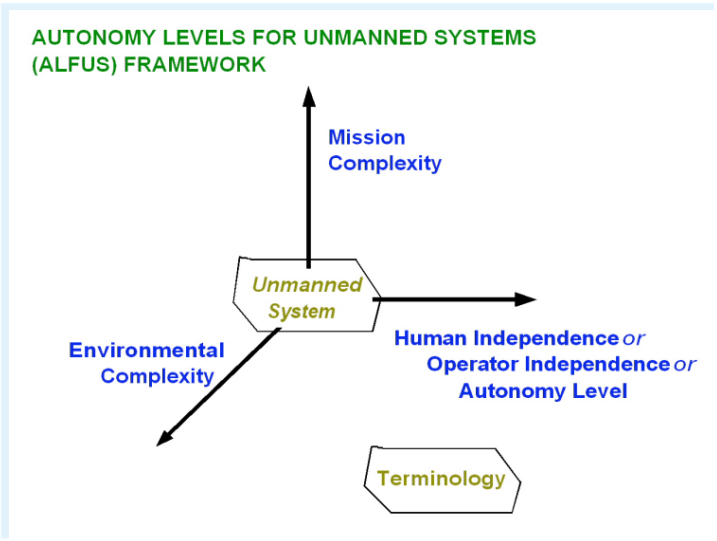
Long Term

Motivations for Military SHM Guidelines 2/4
Trends in Military Air Systems

Definition : Autonomous systems are systems which are able to perform mission without or with limited human involvement or supervision

Alfus framework : Evaluation of autonomy at mission level upon three parameters :

- Human independence
- Environment complexity
- Mission complexity



Safety Assessment

- **Functional Hazard Assessment: Identify & clarify failures and hazards**
- **Preliminary Safety assessment, establish safety requirements**
- **Common cause analysis**
- **Safety Assessment: verify that the system as implemented meets the safety requirements**

System Architecture

- Identify the system elements and set the relationship to join them to a system

Safety Requirements

- Develop Design Assurance Level to prevent failure
- Develop requirements to prevent faiures
- Detail requirements: operational, performance, physical, interface, reliability and maintainability

Validation

Design, Implementation and Test & Evaluation

Integration, Test, Evaluation and Flight Tests

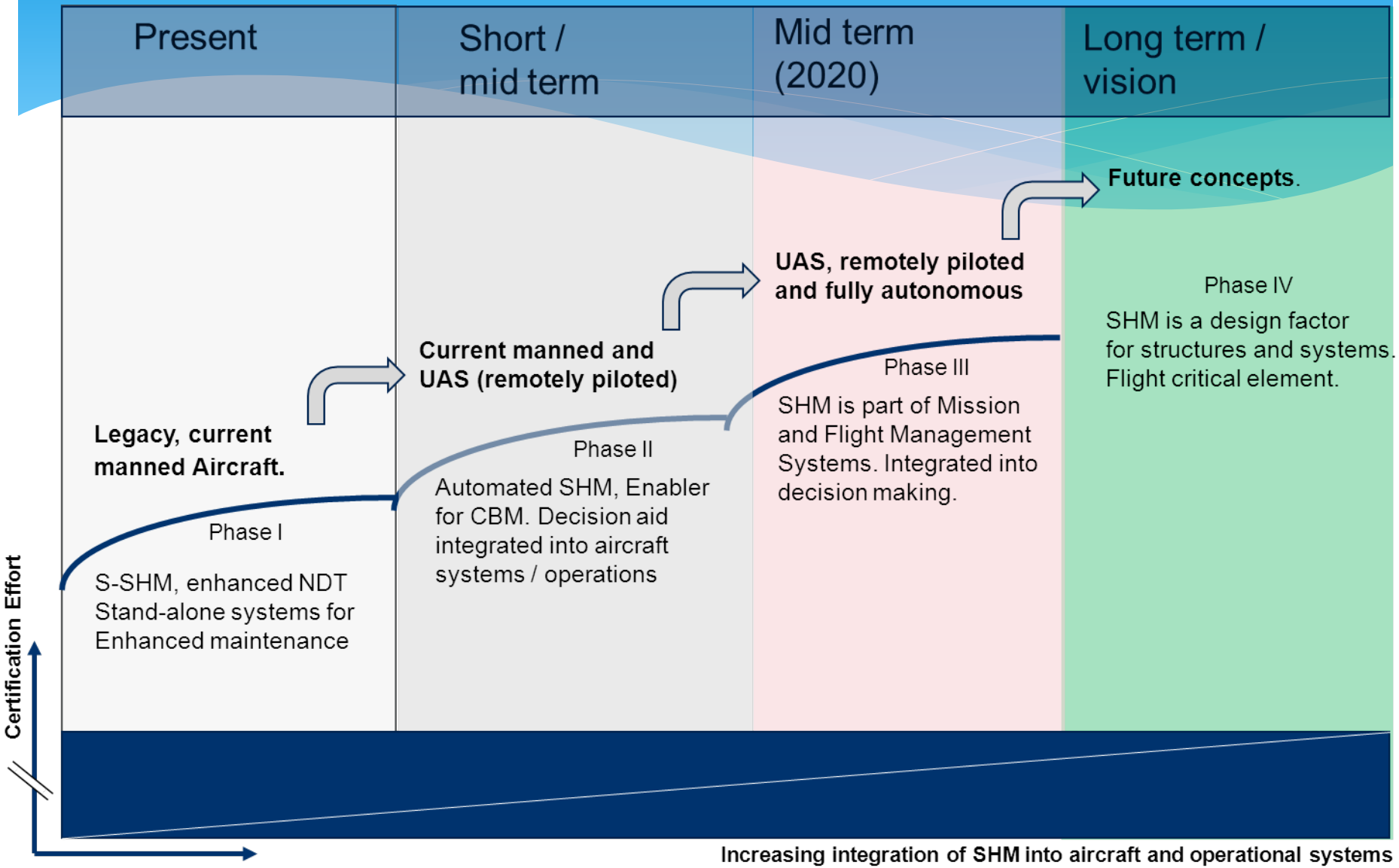
Verification

Instructions for production, installation and operation

Configuration Management

Motivations for Military SHM Guidelines 3/4

Evolution Phases of SHM Systems - Roadmap



Motivations for Military SHM Guidelines 4/4

Main challenges from a OEM & Integrator perspective

- Provide robust SHM system requirements to meet short-, mid-and long term objectives
- Integrate SHM monitoring concept into structural design development process
- Provide safety assessment and requirements to integrate SHM into the health management system ➔ condition based maintenance
- Provide safety assessment and requirements to integrate SHM into the aircraft airborne architecture and interfacing with Mission Management System ➔ autonomous mission execution
- Provide safety assessment and requirements to integrate SHM into the aircraft airborne architecture and interfacing with Flight and Mission Management System ➔ self reliant platform

Contribution of ARP6245 Guidebook

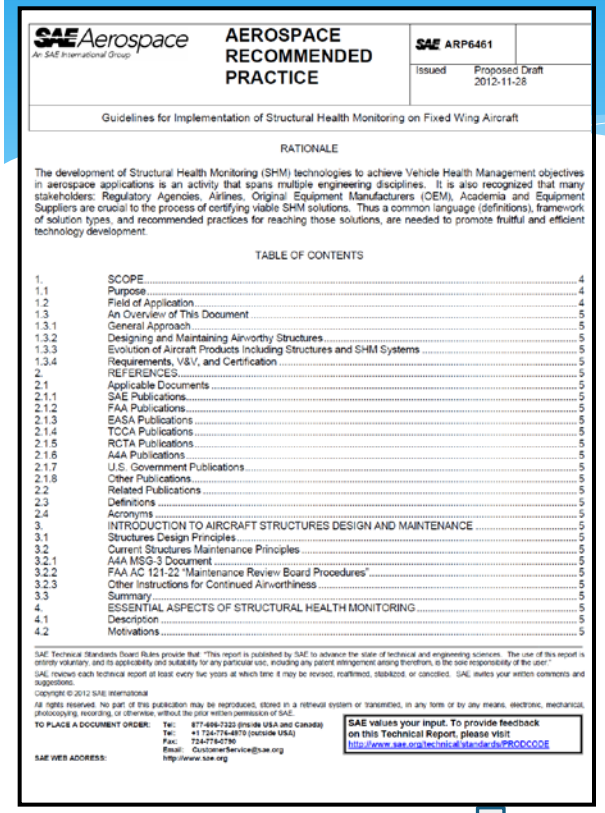
- The military guidelines, ARP6245 should provide concise information about military requirements, processes, and standards.
- ARP6245 should address the processes, standards and regulations required for integrating SHM into the various aircraft types and their supovide port systems.
- ARP6245 should provide information about the potential new concepts and the processes required for the transition to them from existing processes.
- ARP6245 should provide guidelines covering the wide range of military aircraft types.

CASSIDIAN
AN EADS COMPANY
BAE SYSTEMS
HAHN Spring Ltd

SAE Aerospace
An SAE International Group

- Background Information
- The G-11 AISC Military Aircraft Working Group
- Motivations for Military SHM Guidelines
- Status of Military Guidebook Development
- Competencies and skills required for MAWG
- Concluding Remarks

2012-2013 Military Guidebook Development



SAE Aerospace
An SAE International Group

AEROSPACE RECOMMENDED PRACTICE

SAE ARP6461

Issued Proposed Draft 2012-11-28

Guidelines for Implementation of Structural Health Monitoring on Fixed Wing Aircraft

RATIONALE

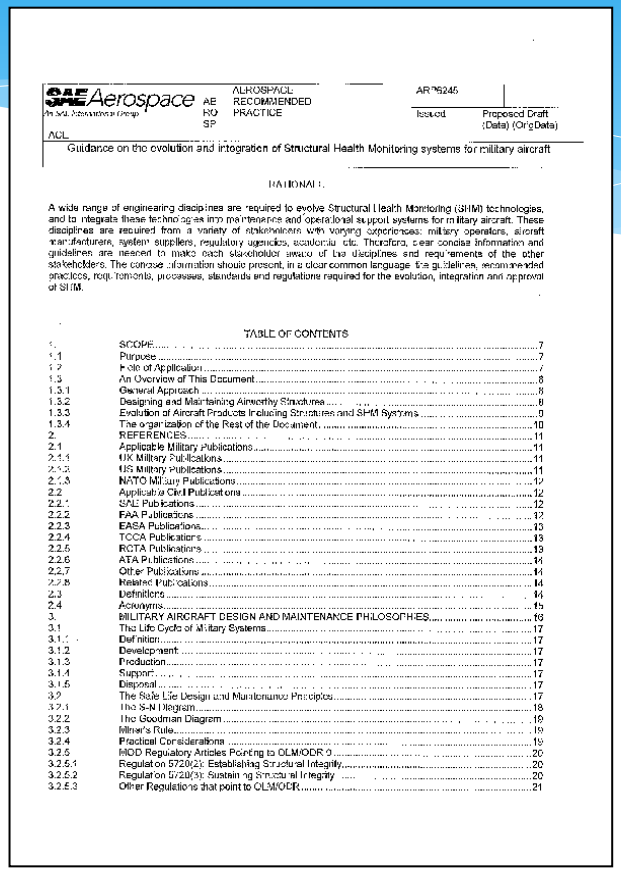
The development of Structural Health Monitoring (SHM) technologies to achieve Vehicle Health Management objectives in aerospace applications is an activity that spans multiple engineering disciplines. It is also recognized that many stakeholders: Regulatory Agencies, Airlines, Original Equipment Manufacturers (OEM), Academia and Equipment Suppliers are crucial to the process of certifying viable SHM solutions. Thus a common language (definitions), framework of solution types, and recommended practices for reaching those solutions, are needed to promote fruitful and efficient technology development.

TABLE OF CONTENTS

TO PLACE A DOCUMENT ORDER: Tel: 877-606-7323 (inside USA and Canada) Tel: +1 724-776-4970 (outside USA) Fax: 724-776-0790 Email: CustomerService@sae.org

SAE WEB ADDRESS: http://www.sae.org

SAE values your input. To provide feedback on this Technical Report, please visit http://www.sae.org/technical/standards/PRODCODE



SAE Aerospace
An SAE International Group

AEROSPACE RECOMMENDED PRACTICE

AE RD SP ACL

ARP6245

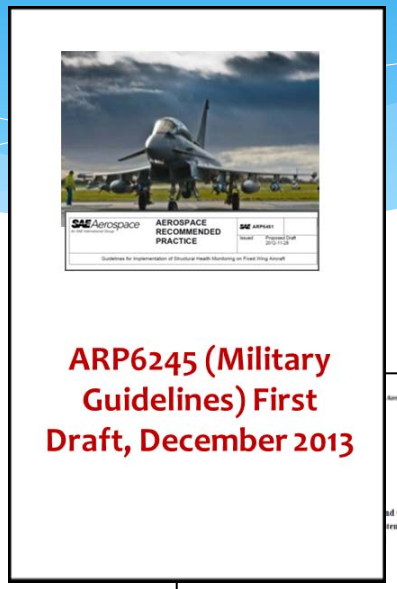
Issued Proposed Draft (Data) (Orig Data)

Guidance on the evolution and integration of Structural Health Monitoring systems for military aircraft

RATIONALE

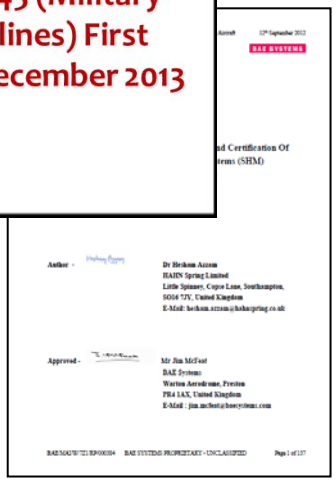
A wide range of engineering disciplines are required to evolve Structural Health Monitoring (SHM) technologies, and to integrate these technologies into maintenance and operational support systems for military aircraft. These disciplines are required from a variety of stakeholders with varying experiences: military operators, aircraft manufacturers, system suppliers, regulatory agencies, academia etc. Therefore, a clear concise information and guidelines are needed to make each stakeholder aware of the disciplines and requirements of the other stakeholders. The concise information should present, in a clear common language, the guidelines, recommended practices, requirements, processes, standards and regulations required for the evolution, integration and approval of SHM.

TABLE OF CONTENTS



SAE Aerospace AEROSPACE RECOMMENDED PRACTICE

ARP6245 (Military Guidelines) First Draft, December 2013



Author - Dr Hesham Azzam, HAHN Spring Limited, Little Spinner, Copse Lane, Southampton, SO16 7JY, United Kingdom, E-Mail: hesham.azzam@hahnspring.co.uk

Approved - Mr Jim McFeat, BAE Systems: Warton Aerodrome, Preston, PR4 1AX, United Kingdom, E-Mail: jim.mcfeat@baesystems.com

BAE SYSTEMS PROPRIETARY - UNCLASSIFIED

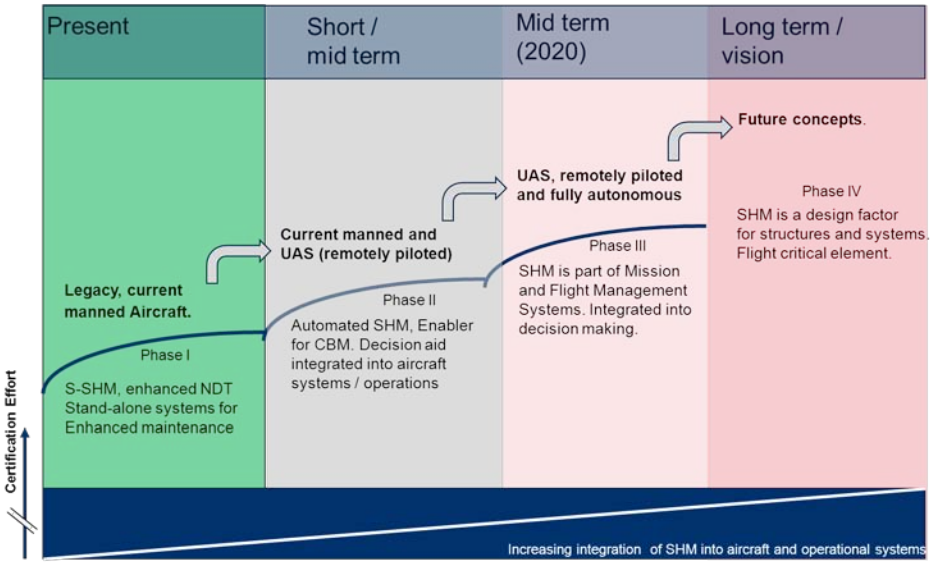
Aerospace Recommended Practice (Civil Guidebook)

Aerospace Recommended Practice (Military Annex) First Draft December 2013

Supporting Dokuments

2012-2013 Military Guidebook Development

Evolution Phases of SHM Systems – Phase I – Lessons Learned



Legacy A/C and current Fleets

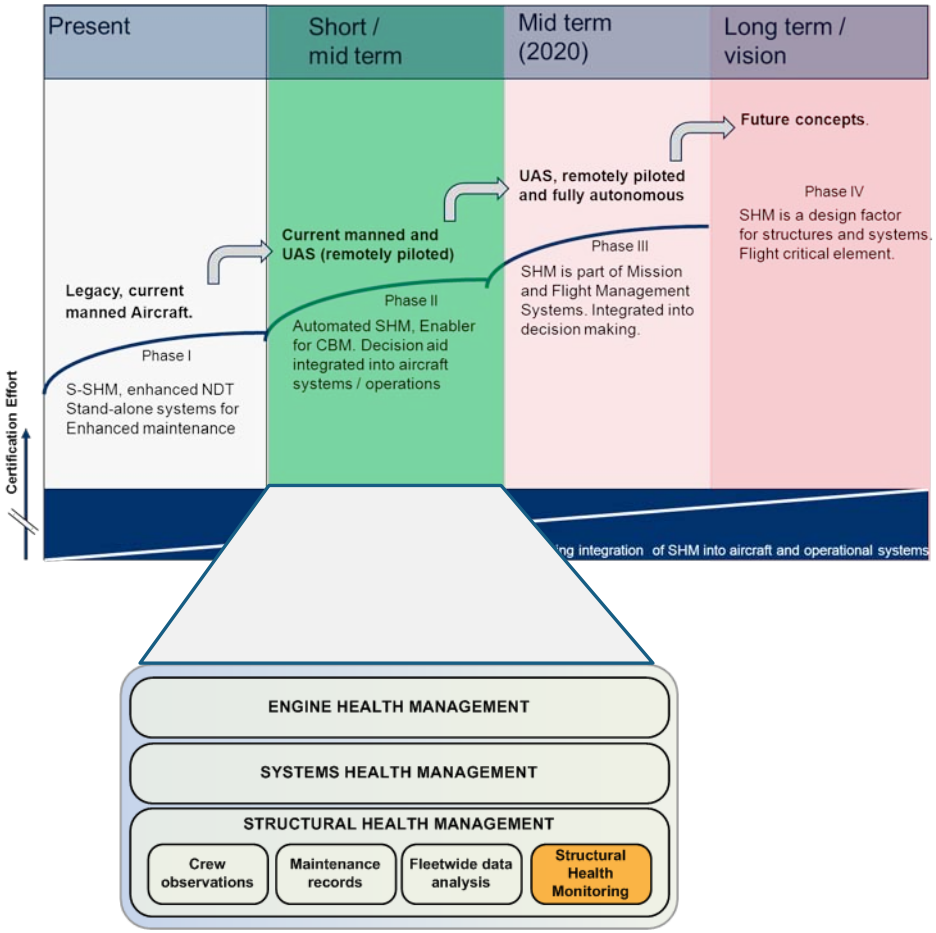
Timescale: Present

- More efficient NDT process
- Stand-alone system
- Lower training requirements
- Faster turnaround for inspections
- Reduced human factors
- Uses S-SHM (MSG-3 rev. 20019.1)

- **Issues / gaps:**
- The above must be harmonised with global maintenance practices.

2012-2013 Military Guidebook Development

Evolution Phases of SHM Systems – Phase II - Lessons Learned



Legacy A/C, current manned and UAS fleets

Timescale: Short / mid term

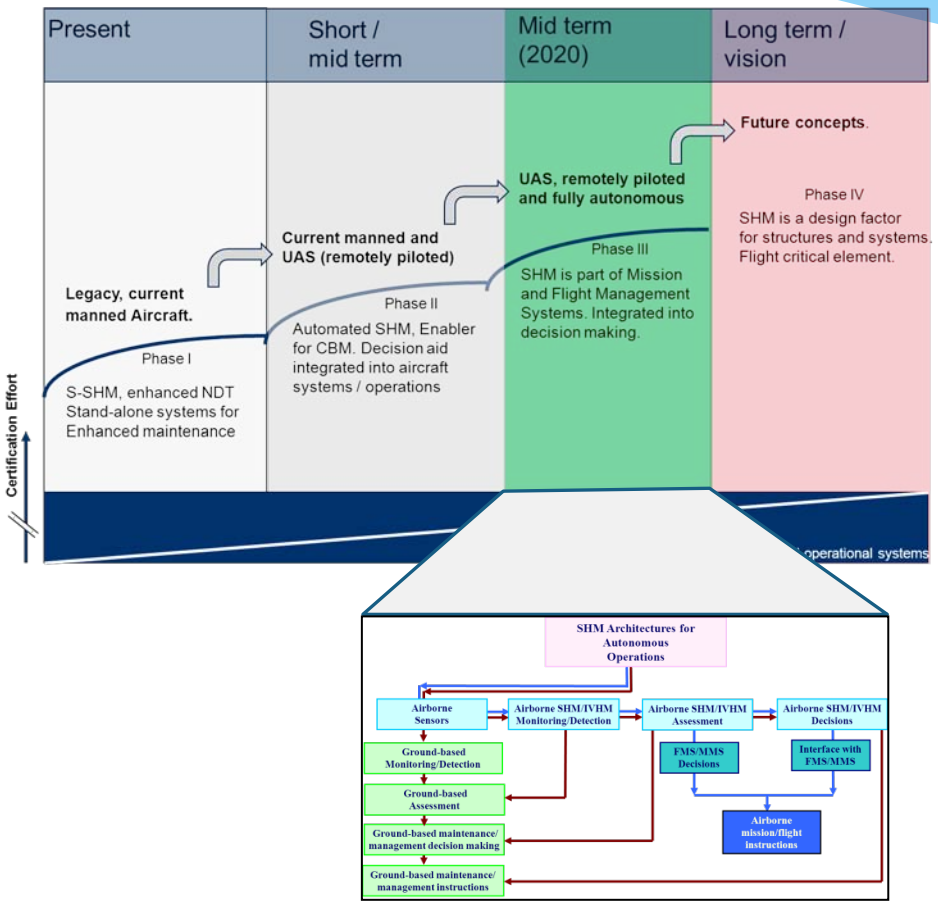
- Automated SHM (A-SHM)*. System reports degradation automatically. No human interaction to produce inspection result.
- Enabler for CBM, CBM+ (change maintenance intervals)
- Used as a decision aid.
- Integrated into aircraft support systems.
- Integrated in aircraft operational systems (for UAS**)

Issues / gaps:

- Significant effort for certification needed.
- System integration & verification roadmap required.
- Dependency on system to inform on functional availability of the structure
- * See MSG-3 Issue Paper IP 105
- ** Remotely piloted and fully autonomous

2012-2013 Military Guidebook Development

Evolution Phases of SHM Systems Phase III - Lessons Learned



RP, FA* UAS fleets

Timescale: Mid term

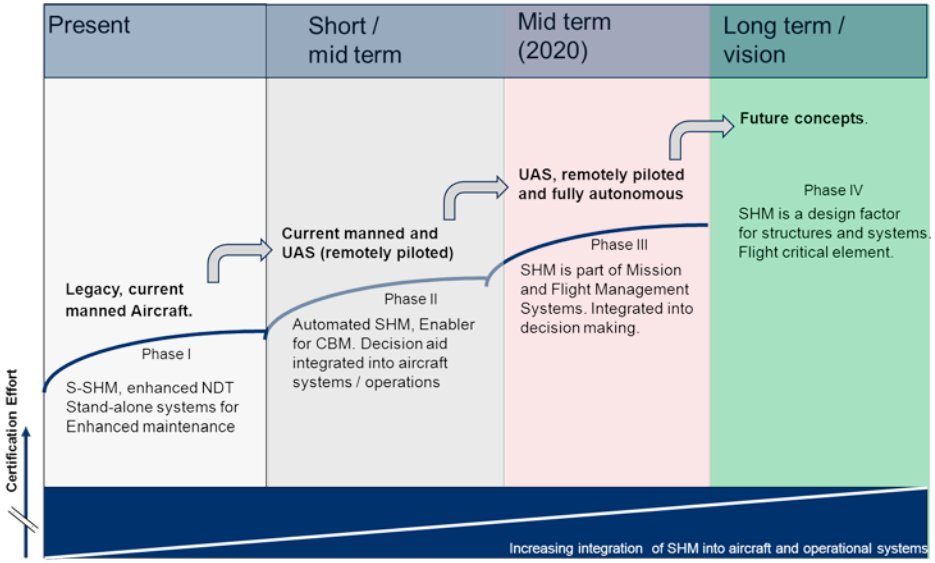
- SHM sub-systems, components, items and functions are fully integrated within the aircraft airborne architecture and interfacing with MMS/FMS
- Development Assurance Level (DAL) is assigned to each item and function based on the classification of related failure conditions
- Validation/verification data and methods described in this document would be required to support certification.
- Standardization of IVHM / SHM HW / SW architecture

Issues / gaps:

- Missing regulatory environment: civil and military.
- Validation/verification data and methods
- Standardisation

2012-2013 Military Guidebook Development

Evolution Phases of SHM Systems – Phase IV - Lessons Learned



UAS fleets and future concepts

Timescale: Long term / vision

- SHM changes / influences structure and system design criteria

Issues / gaps:

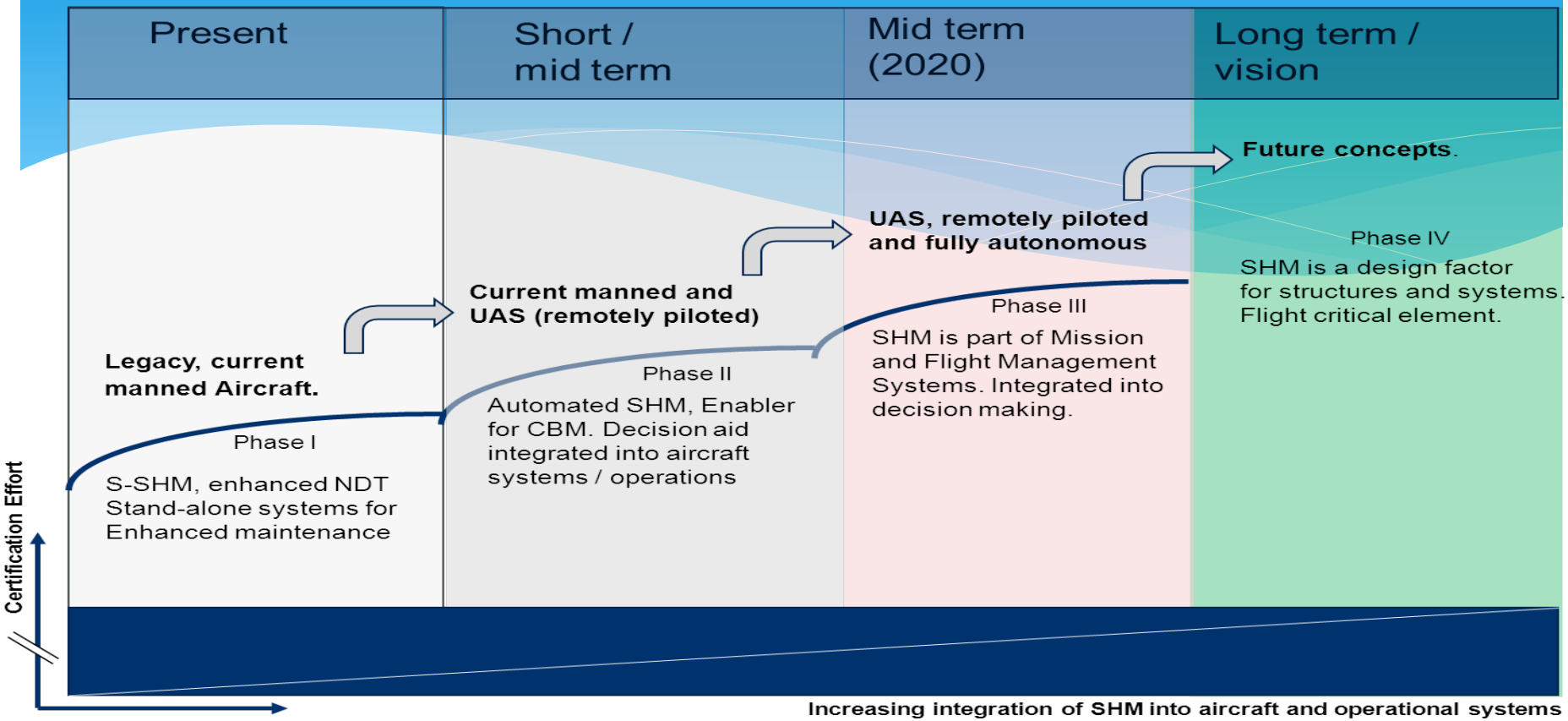
- Change of regulations and rules required (fundamental)

CASSIDIAN
AN EADS COMPANY
BAE SYSTEMS
HAHN Spring Ltd

SAE Aerospace
An SAE International Group

- Background Information
- The G-11 AISC Military Aircraft Working Group
- Motivations for Military SHM Guidelines
- Status of Military Guidebook Development
- Competencies and skills required for MAWG
- Concluding Remarks

Competencies and skills required to support MAWG



- Structural and systems engineering
- Regulatory know-how
- Support and maintenance engineering

- System architecture design
- System integration
- ISHM / IVHM expertise (e.g links to SAE IVHM Initiative

- Configuration Mgt.
- Maintenance Mgt.
- Mission Mgt.
- SW Engineering

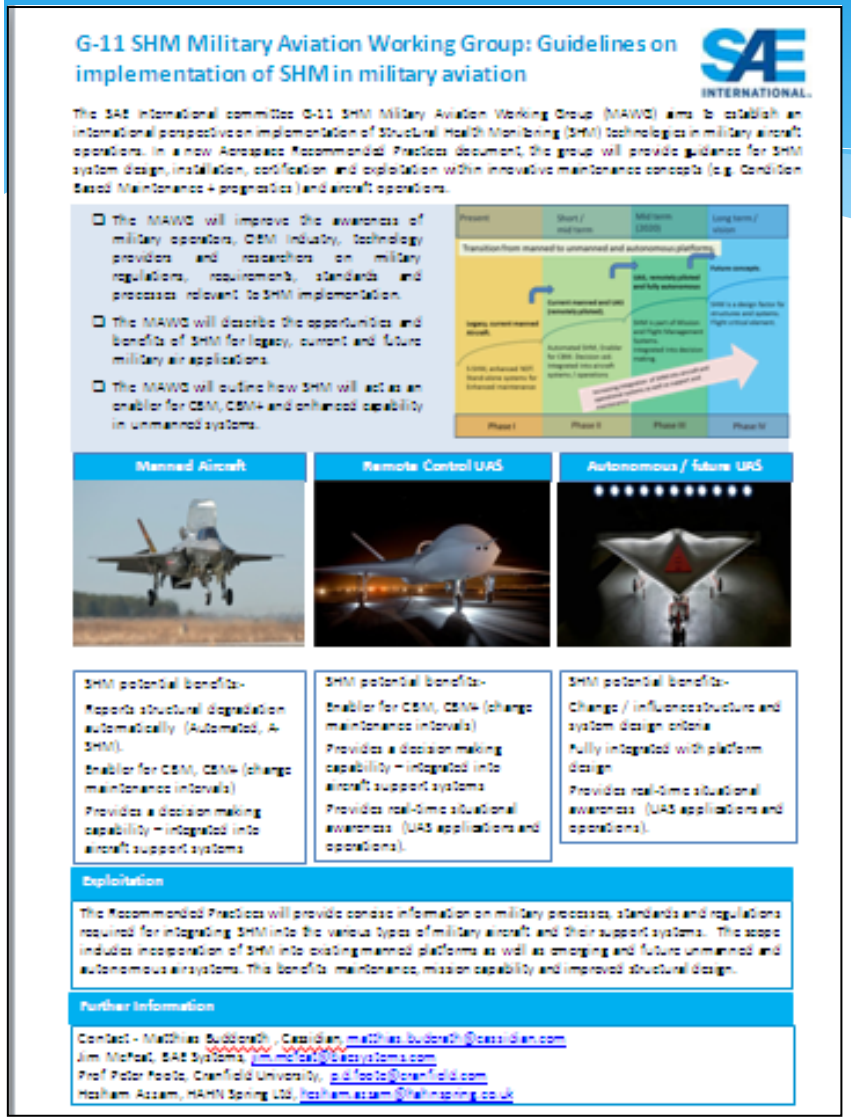
- Structures design and analysis experts
- Damage tolerance experts
- Conceptual design engineers

Concluding Remarks

- The G-11 AISC team developed **ARP6461** for SHM civil transport aircraft applications.Some of the guidelines **ARP6461** will be re-used for military aircraft.
- **ARP6461** does not address specific military considerations and does not cover the wider spectrum of military aircraft types; the scope of **ARP6461** did not include guidance on the integration of SHM into the aircraft and its military aircraft support systems.
- Therefore, AISC decided to compile **ARP6245** to cover the topics that are not considered by the civil ARP.
- The work on the military ARP document started early 2013 and benefited from previous work carried out by BAE Systems, Cassidian and HAHN Spring Ltd.
- Currently MAWG assembles members from Cassidian, BAE Systems, Boeing, US Air force, NAVAIR, Embraer, Honeywell, HAHN Spring Ltd, UTC Aerospace Systems, Cranfield University, Stanford University and TU Deflt.
- Further military and industrial organizations have expressed interest and will join MAWG in the near future.

The efforts of this international committee should produce an initial draft by the end of 2013. The leads of MAWG have set a challenging timescales aiming for agreed and approved military guidelines by the end of 2014.

Poster Session



G-11 SHM Military Aviation Working Group: Guidelines on implementation of SHM in military aviation

SAE INTERNATIONAL

The SAE international committee G-11 SHM Military Aviation Working Group (MAWG) aims to establish an international perspective on implementation of Structural Health Monitoring (SHM) technologies in military aircraft operations. In a new Aerospace Recommended Practices document, the group will provide guidance for SHM system design, installation, certification and exploitation within innovative maintenance concepts (e.g. Condition Based Maintenance + prognostics) and aircraft operations.

- The MAWG will improve the awareness of military operators, OEM industry, technology providers and researchers on military regulations, requirements, standards and processes relevant to SHM implementation.
- The MAWG will describe the opportunities and benefits of SHM for legacy, current and future military air applications.
- The MAWG will outline how SHM will act as an enabler for CBM, CBM+ and enhanced capability in unmanned systems.

Manned Aircraft

Remote Control UAS

Autonomous / future UAS

SHM potential benefits:
Reports structural degradation automatically (Automated, A-SHM).
Enabler for CBM, CBM+ (change maintenance intervals)
Provides a decision making capability – integrated into aircraft support systems

SHM potential benefits:
Enabler for CBM, CBM+ (change maintenance intervals)
Provides a decision making capability – integrated into aircraft support systems
Provides real-time situational awareness (UAS applications and operations).

SHM potential benefits:
Change / influence structure and system design criteria
Fully integrated with platform design
Provides real-time situational awareness (UAS applications and operations).

Exploitation

The Recommended Practices will provide concise information on military processes, standards and regulations required for integrating SHM into the various types of military aircraft and their support systems. The scope includes incorporation of SHM into existing manned platforms as well as emerging and future unmanned and autonomous air systems. This benefits maintenance, mission capability and improved structural design.

Further Information

Contact - Matthias Buderath, Cassidian, matthias.buderath@cassidian.com
Jim Moffatt, BAE Systems, jim.moffatt@baesystems.com
Prof Peter Foote, Cranfield University, p.d.foote@cranfield.com
Hosham Assam, HAMI Spring Ltd, hosham.assam@hamispring.co.uk

If you want further information please come and talk to us at the poster session