



## **– BUILDING A SAFER SPACE TOGHETER –**

***“ISHEM technologies to improve safety in  
next generation space vehicles:  
from aeronautics to space”***

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## **PURPOSE**

**Understand how ISHEM concepts could impact on the future space vehicles programs, starting from knowledge matured in aeronautics applications, in the perspective of a synergistic approach in health management.**



## AGENDA

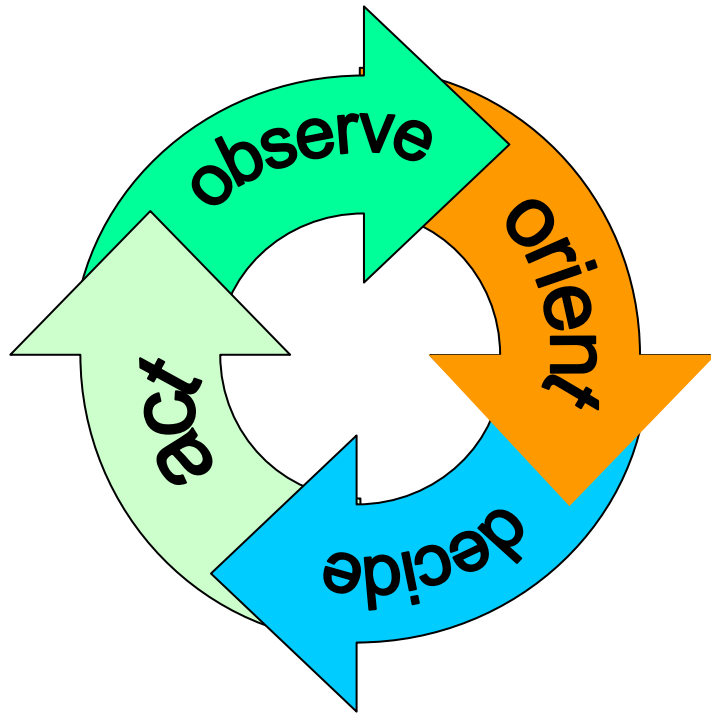
- ✓ **Introduction**
- ✓ **Health management concept evolution**
- ✓ **State of art in EFA and JSF. Lesson learned**
- ✓ **Next generation space vehicles perspective**
- ✓ **Conclusions and way ahead**



## INTRODUCTION

### Health management systems approach?

### Boyd Theory – OODA Loop strategy



- ✓ It is an iterative loop.
- ✓ It is a behavioral model that can be generalized.
- ✓ The faster is closed the better it is.

**How to react to an event? OODA = Observe, Orient,  
Decide, Act**



## HEALTH MANAGEMENT CONCEPT EVOLUTION

<b>SHM</b>	<b>Structural Health Monitoring</b>	1960
<b>VHM</b>	<b>Vehicle Health Monitoring</b>	1970
<b>IVHM</b>	<b>Integrated Vehicle Health Monitoring</b>	1980
<b>ISHM</b>	<b>Integrated Systems Health Monitoring</b>	1990
<b>ISHM</b>	<b>Integrated Systems Health Management</b>	2000
<b>ISHEM</b>	<b>Integrated Systems Health Engineering &amp; Management</b>	2003



## HEALTH MANAGEMENT CONCEPT EVOLUTION

# ISHEM

*“Processes, techniques and technologies used to design, analyze, build, verify and operate a system to prevent faults and/or mitigate their effects”*

**Diagnostics.** Determine state of components and detect failures.

**Prognostics.** Predict and determine the useful life by modeling faults progression.

**Health Management.** Make appropriate decisions about maintenance, logistics and operational actions



# State of art in EFA and JSF

## Lesson learned



## STATE OF ART IN EFA AND JSF

### Eurofighter Program

- **Multi role weapon system for air superiority and air-to-surface missions**
- **Joint program (IT, UK, GE, SP)**
- **Integrated sensors and data fusion for pilot situation awareness**
- **Extensive use of prognostic and built-in test equipment**
- **Advanced logistics support concept**
- **Low requirement for scheduled maintenance (less than half required on other in-service aircrafts)**
- **Life cycle cost minimized (theoretically)**



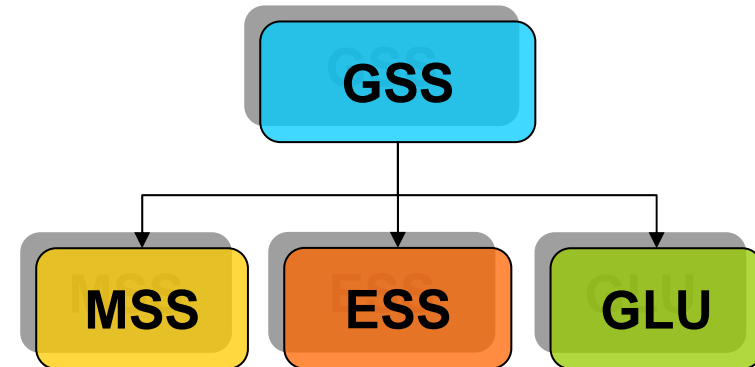


## STATE OF ART IN EFA AND JSF

### Eurofighter Program

The Engineering Support Subsystem (ESS) provides the functionalities related to

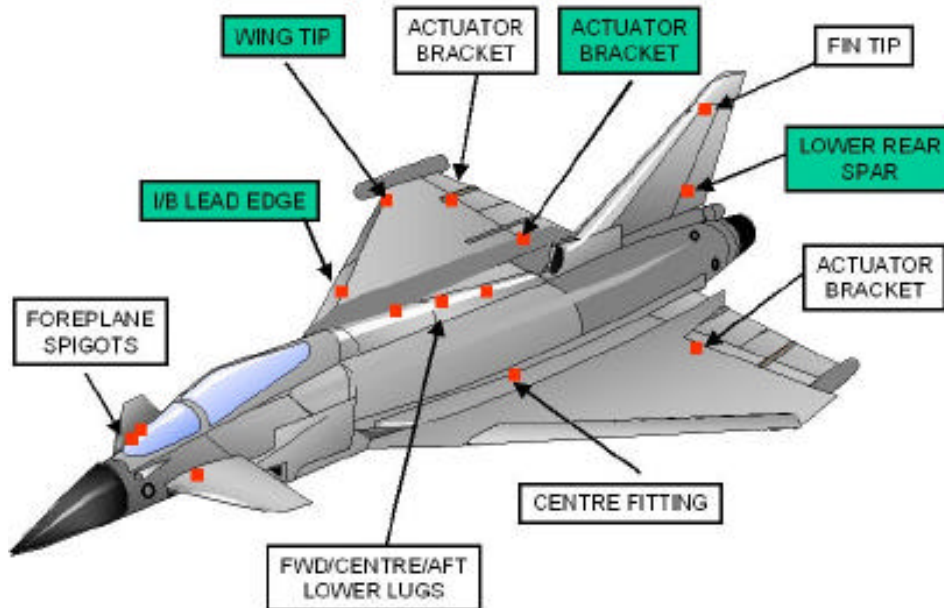
- A/C Systems Health Monitoring,
- Structural Health Monitoring,
- Engine Health Monitoring,
- SPS Health Monitoring,
- Engineering Data Management,
- Pubs and configuration management,
- Fleet Data Management.



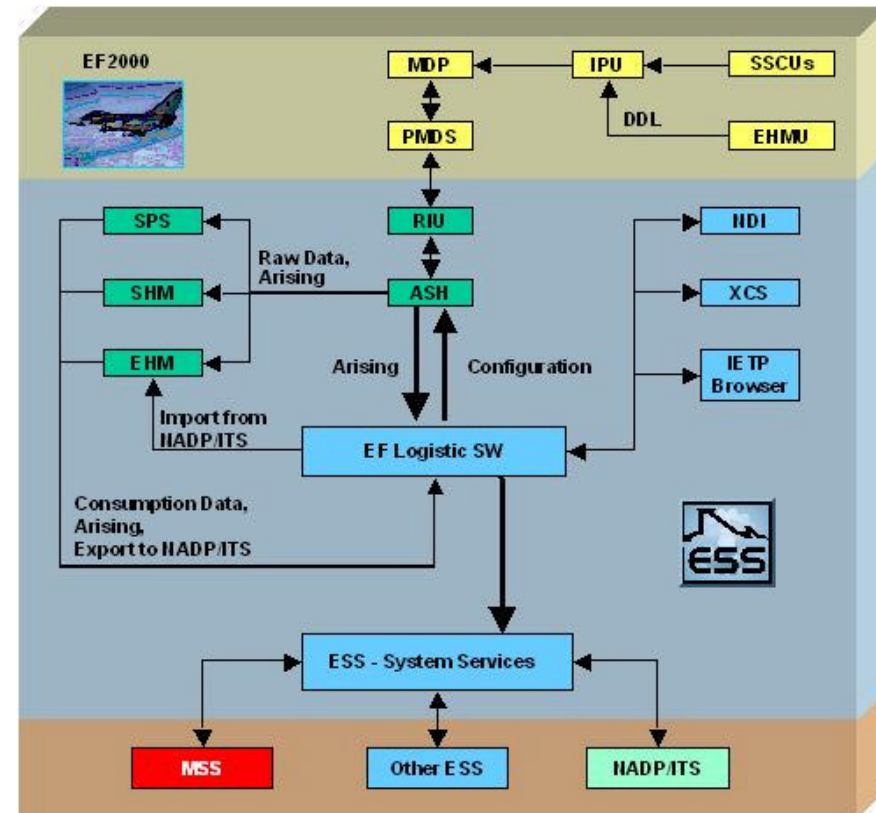
*GSS Ground Support System*  
*MSS Mission Support System*  
*ESS Engineering Support System*  
*GLU Ground Loading Unit*

## STATE OF ART IN EFA AND JSF

# Eurofighter Program



**distributed strain gauges**  
**engine vibrations**  
**parameters equations based on flight data**





## STATE OF ART IN EFA AND JSF

### Joint Strike Fighter Program

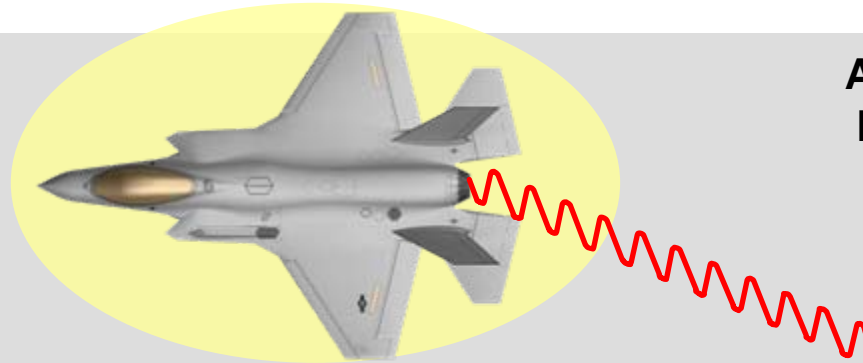
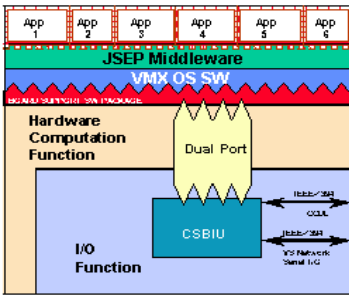
- **Multi role weapon system for air superiority with stealth features.**
- **US program open to international partnership (UK, Italy, Norway, Holland, Denmark, Canada)**
- **Single engine (Pratt&Witney)**
- **CTOL and VTOL versions**
- **Integrated sensors and data fusion for pilot situation awareness**
- **Extensive use of prognostic and built-in test equipments**
- **Advanced logistics support concept**



**STATE OF ART IN EFA AND JSF**

**Joint Strike Fighter Program**

**Enhanced Prognostics**

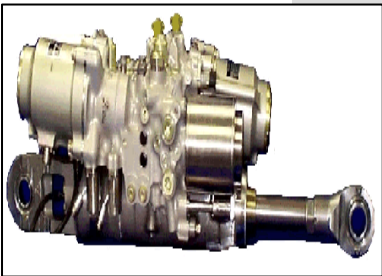


**Autonomic Logistics Information System**

**ALIS**

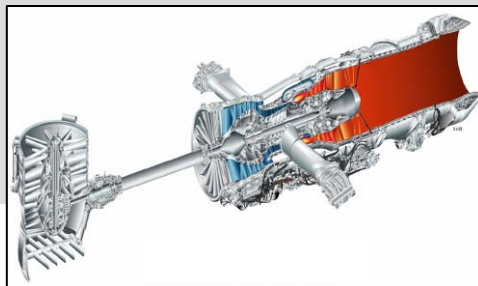


**Equipments BIT**

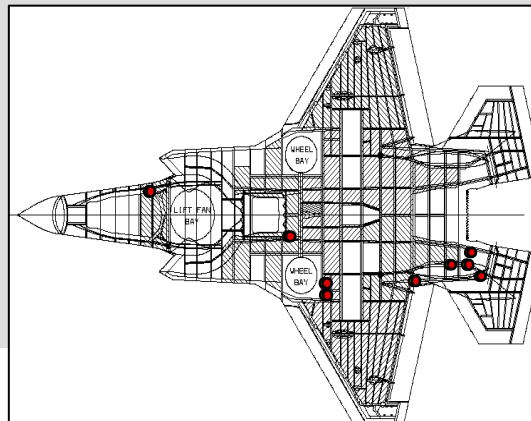


**FADEC  
Engine Vibration  
Debris Monitoring  
Fan Blade Monitor**

**EHM**



**SHM**



**Strain sensors  
Fatigue index  
Corrosion**



## Expected benefits from ISHEM approach

- Enhance reliability & global safety.
- Optimize the logistics footprint (less spare parts and manpower) and fleet management.
- Reduce scheduled inspections.
- Provide real time notification & health reporting.
- Support in decision making process.
- Reduce Life Cycle Cost.
- Detect & monitor incipient faults until just to failure.
- Calculate equipments and components residual life



## JSF and EFA Lesson Learned

- ✓ **ISHEM is Multi-Disciplinary, Multi-Functional, Multi-Technology.**
- ✓ **PHM capabilities have to be integrated since the conceptual phase (no add-on approach).**
- ✓ **New technologies introduction requires an updating of the engineering processes, procedures and standards.**
- ✓ **Need good Diagnostics before doing Prognostics.**
- ✓ **ISHEM technologies are doable in many but not all cases (trade off studies are needed).**
- ✓ **Prognostics Capabilities take time to mature**
- ✓ **PHM Algorithms need to be widely tested and verified.**



## STATE OF ART IN EFA AND JSF

### JSF and EFA Lesson Learned

- ✓ ISHEM is Multi-Disciplinary, Multi-Functional, Multi-Technology.
- ✓ PHM capabilities have to be integrated since the conceptual phase (no add-on approach).
- ✓ New technologies introduction requires changes in the engineering processes and tools.
- ✓ Need good Diagnostic and Prognostic capabilities.
- ✓ ISHEM is not a silver bullet. It is a necessary but not all cases (trade-offs).
- ✓ Prognostic capabilities take Time to Mature.
- ✓ PHM capabilities Need to be widely tested and verified.

**JSF Program Office foresees more than 200.000 flight hours experience to reach an adequate technologies readiness**



# Next generation space vehicles perspective

## NEXT GENERATION SPACE VEHICLES PERSPECTIVE

### Main goals for next generation space vehicles programs:

**Based on recent experience:**

- ✓ **Increase overall safety**
- ✓ **Reduce total costs**





## NEXT GENERATION SPACE VEHICLES PERSPECTIVE

**SAFETY** is a paramount objective in Human Spaceflight future activities.



**STS – 51L Challenger  
(during ascent phase – 26.01.1986)**



**STS – 107 Columbia  
(during reentry – 01.02.2003)**



**NEXT GENERATION SPACE VEHICLES PERSPECTIVE**

**Accidents have often emphasized lack in design and certification process and demand for new technological solutions:**

**First failures at loads lower than ultimate**



**Fatigue damage concept**

**COMET service failures**



**Damage tolerance concept (1978)**

**Aloha Airlines accident**



**Widespread fatigue damage (1988)**

**Columbia accident**



***Health Monitoring System??***



## NEXT GENERATION SPACE VEHICLES PERSPECTIVE

# SAFETY

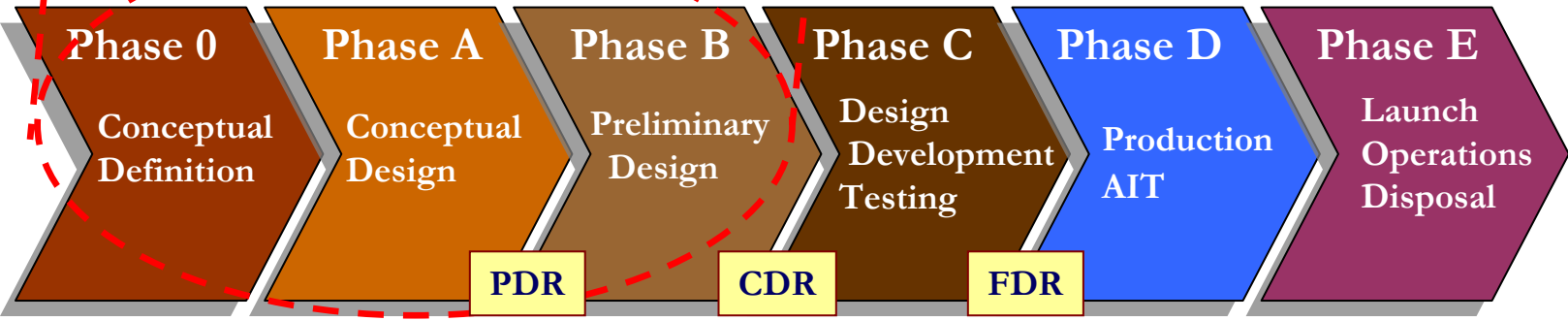
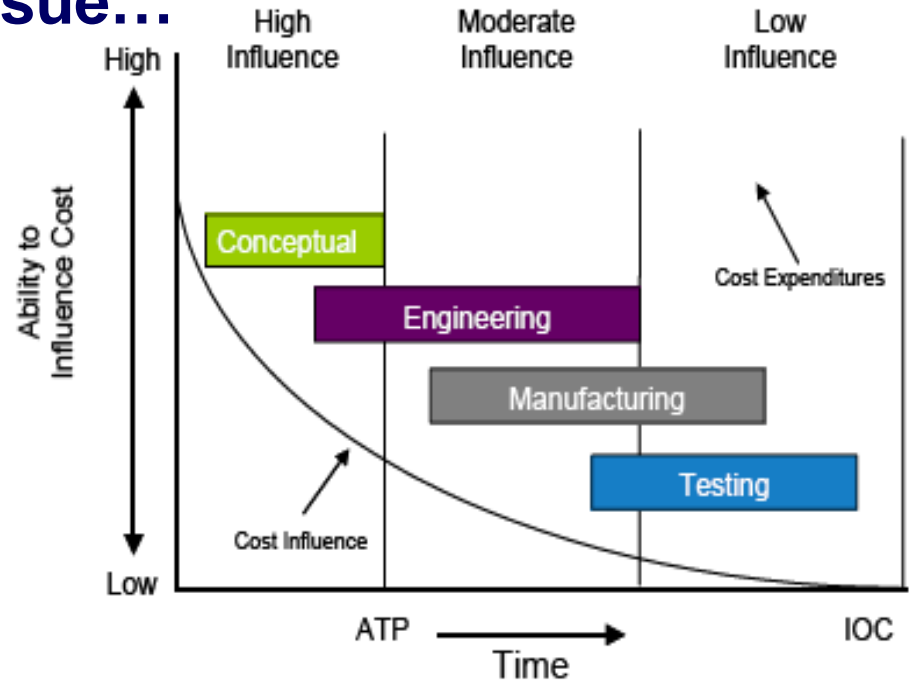
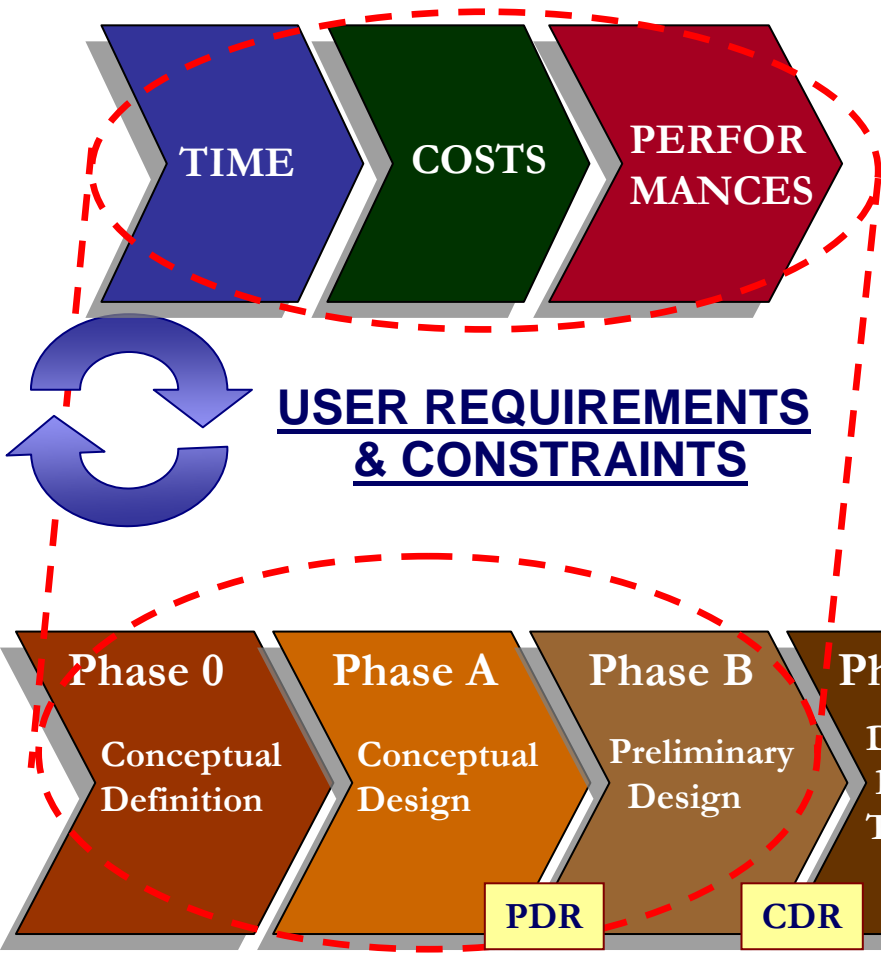
**“THE MINIMIZATION OF RISK FROM DAMAGE OR HARM TO HARDWARE, SOFTWARE, FACILITIES, OR HUMANS”  
(NASA Procedures and Guidelines.8705.2A)**

***“NASA should establish a system of analyzing and reporting performance trends of most critical items.” (Report of the Presidential Commission on the Space Shuttle Challenger Accident. In compliance with Executive Order 12546 of February 3, 1986)***



# NEXT GENERATION SPACE VEHICLES PERSPECTIVE

## ..Safety is a cost – effective issue...





**According with aeronautics experience if we want reduce the life cycle cost it is mandatory:**

- ✓ **State clearly the users requirements**
- ✓ **Identify the main cost drivers**
- ✓ **Develop adequate architecture models**
- ✓ **Fulfill a risk assessment**
- ✓ **Think in terms of the entire Life Cycle Cost (non-recurring + recurring + logistics + operations costs)**



## NEXT GENERATION SPACE VEHICLES PERSPECTIVE

According with aeronautics experience if we want to reduce the life cycle cost it is mandatory:

✓ State clearly the users requirements

✓ Identify the main cost drivers

✓ Develop adequate

✓ Fulfill

✓ Minimize the entire Life Cycle Cost (non-recurring + logistics + operations costs)

**Even doing so,  
we are not sure that  
the final cost will be affordable**



# Conclusions & Way Ahead

## CONCLUSIONS

**ISHEM technologies implementation and integration in aerospace systems are useful to improve**



- **Safety**
- **Reliability**
- **Availability**
- **Maintainability**
- **Supportability**
- **Affordability**



## CONCLUSIONS

- 1. ISHEM may concur to improve the global level of safety throughout the entire program envelope.**
- 2. A lot of enhancements are still needed to reach the necessary level of reliability of such technologies (EFA/JSF experience).**
- 3. It necessary to assess safety requirements since the very beginning of the engineering process.**
- 4. Cost effort to develop such systems could be unaffordable.**

**So.....**



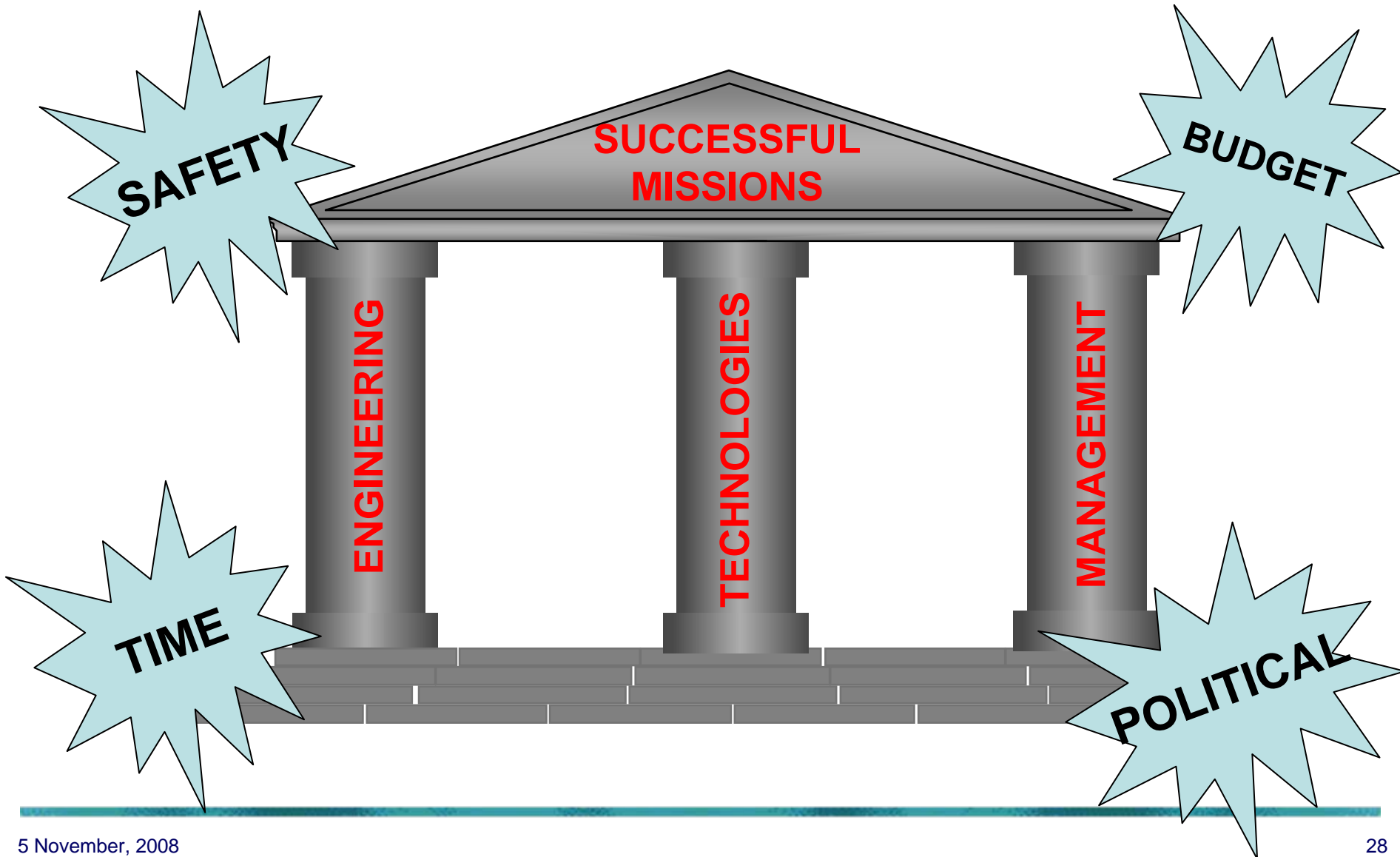
## CONCLUSIONS

**.....It is strongly desirable:**

- Join the aeronautics and space effort in a synergistic approach especially in research & development phase.**
- Perform some necessary trade-off, since the conceptual phase, to evaluate cost – effectiveness of the initial requirements.**
- Integrate safety requirements in a new architectural approach, based on updated procedures and engineering processes.**



## CONCLUSIONS





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