Model Based Enterprise & Human System Integration Fundamentals

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Overview

Main themes:

1. Fundamentals and Goals of Enterprise Architecture Frameworks (GAB, OD)
2. Selected EA Frameworks TOGAF, EA3, UAF, BPMN (OD)
3. Enterprise Readiness (GAB)
4. Space Enterprise Architecture Frameworks (OD)
5. Challenges of Enterprise Transformation (GAB, OD)
6. *Moon Resources - Mini-project Specification*

References:

- HBR

- Design Thinking, Harvard Business Review - https://hbr.org/2019/03/the-right-way-to-lead-design-thinking
- Business Human-Centered Design
- Boy, 2021, Socioergonomics: A few clarifications on the Technology-Organizations-People Tryptic, INCOSE
- *TOGAF, https://www.erp-information.com/togaf-framework*
- *UAF, https://www.omgwiki.org/uaf/doku.php*
- *Bernard, 2012, An Introduction to Enterprise Architecture: Third Edition*

HSI definitions /Glossary

HCD – Human Centered Design

HSI – Human System Integration

HF – Human Factors

HFE – Human Factors Engineering

NASA – National Aeronautics and Space Administration

ORL – Organizational Readiness Level

HRL – Human Readiness Level

SE – System Engineering

TRL – Technology Readiness Level

HITL – Humans In The Loop simulations

UAF – Unified Architecture Framework

UAFML - Unified Architecture Framework Modeling Language

SysML – Systems Modeling Language

EA – Enterprise Architecture

TOGAF – The Open Group Architecture Framework

OMG – Object Management Group

NASA/TP – Technical Paper

HIDP – Human Integration Design Processes

HSIPG – Human-System Integration Practitioner's Guide

HSIP – HSI Plan

SOH – Safety and Occupational Health

SAE – Society of Automotive Engineers

DoD – Department of Defense of United States of America

SME – Subject Matter Expert

(SME – Small Medium Enterprise)

KPI – Key Performance Indicator

FPS – Force Protection and Survivability

LCC – Lifecycle Cost

LRU – Line Replacement Unit

ORU – Orbital Replacement Unit

ROI – Return On Investment

VR – Virtual Reality

Part 1

FUNDAMENTALS AND GOALS OF ENTERPRISE ARCHITECTURE FRAMEWORKS

Mini-project - EA Overview

Project/Program

Enterprise: An organization or activity whose boundary is defined by commonly accepted goals, processes and resources.

Strategy

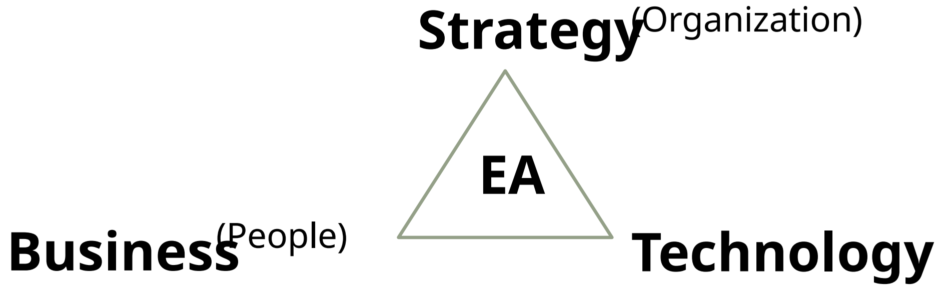
Architecture: A systematic approach or (framework), that leads, organizes and system design, analysis, planning, and documentation activities

Project Strategy

Enterprise Architecture: A holistic approach to sociotechnical system analysis, documentation and modeling in its current, transition and future states from an integrated strategy, business, and technology perspective.

EA assists in enterprise-wide planning and decision-making. It provides a number of differing yet coordinated views of the entire enterprise, and consists of both a management program and a framework-based/model-based system of system methodology.

EA Overview



EA needs to consider strategic goals, business requirements, and technology capabilities

Current EA

Starting new enterprise or mapping existing enterprise against selected **EA Framework**, using **a modeling Tool**, and choosing a **modeling language**, requires significant time investment and skills for decomposition complexity.

EA Transition Model
EA Transition Management

Transition model indicates how, step by step, will the current EA be transformed in the Future EA. EA management describes how to manage this transition

Future EA

Typically, the short-term view will cover approximately the next 1-3 years, and the long-term view will cover approximately the next 4-10 years

Mini-project - EA Overview

Task: Through assigned/selected project topic develop Operations Architecture that includes following element:

1. Identification of Enterprise Stakeholders, Enterprise Goals
2. Create an Enterprise Concept of Operations
3. Selection / definition of Enterprise Framework
4. Describe-develop current EA
5. Describe future EA based on real market data/incentives/potential
6. Identify transformation risks and mitigation techniques
7. Describe main HSI goals and plan of Enterprise transformation
8. Main goals and deliverables of Enterprise transformation

Part 2

SELECTED MODEL BASED EA FRAMEWORKS:

- ZACHMAN
- TOGAF
- UAF
- EA3 CUBE

Zachman – Organize your EA

John Zachman on his framework:

"primitive" but still in use!

EA artifacts to be developed for each of the 30 cells in the 6 column x 5 row schema:
e.g., semantic data models, entity relationship diagrams, node connectivity diagrams, organization charts, and business activity models.

	What	How	Where	Who	When	Why
Planner	The content of these cells defines the scope of the enterprise, identifying what should possibly be modeled.					
Owner	These cell models comprise the Business Model - the Owner's expectations from a business perspective for the operating enterprise.					
Designer	These cell models comprise the technology neutral System Model - the Designer's plan for enabling the Business Model.					
Builder	These cell models comprise the Technology Model - the Builder's plan for applying technology to the System Model.					
Sub-contractor	These cells are listings, identifying the actual solutions that have been implemented.					
Functioning Enterprise	The functioning enterprise.					

John Zachman on his framework (1987) (Information System Architecture – renamed Enterprise System Architecture**):**

"All I did was, I saw the pattern of the structure of the descriptive representations for buildings, airplanes, locomotives and computers, and I put enterprise names on the same patterns," …

"*Now you have the Zachman Framework, which basically is Architecture for Enterprises. It is Architecture for every other object known to human kind." (John Zachman, By The Open Group)*

Zachman

TOGAF – Create and Manage your EA

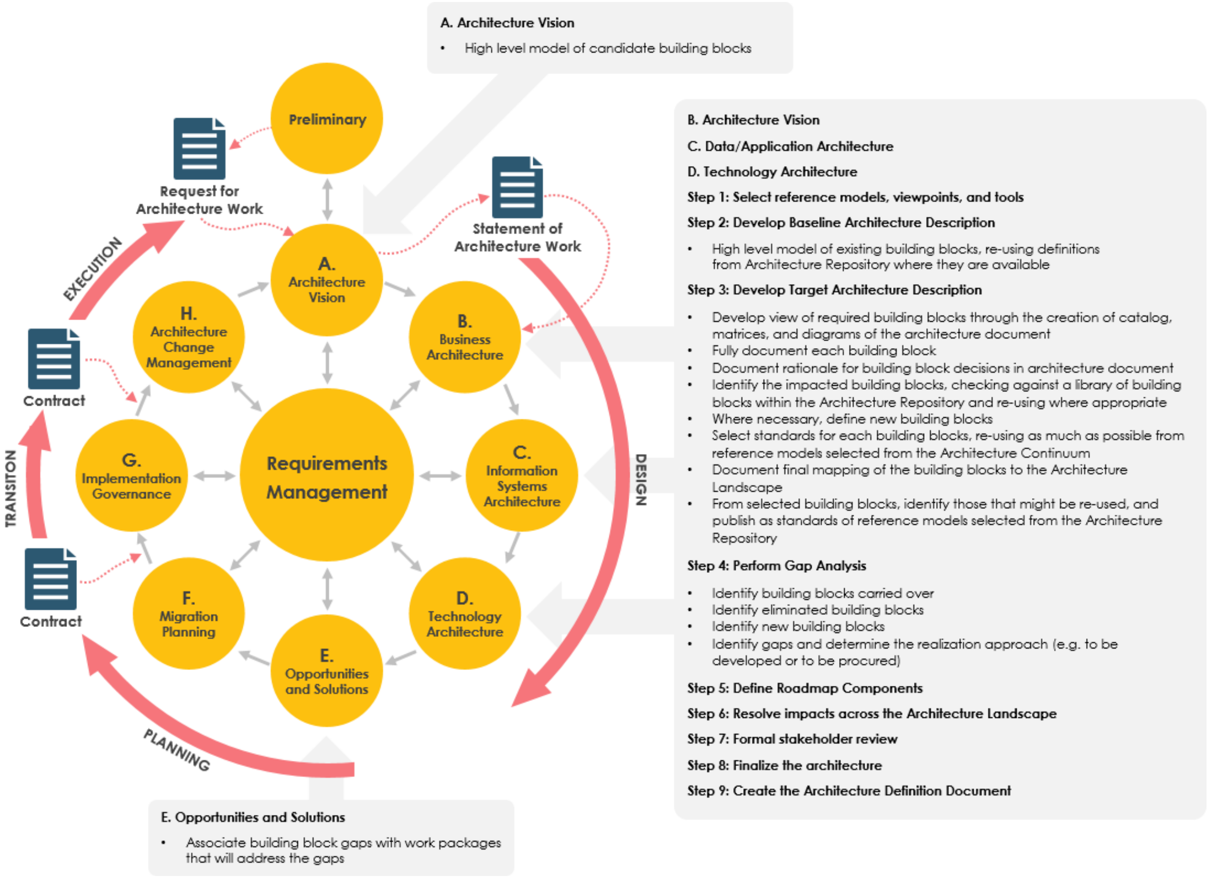
The Open Group Architecture Framework(**TOGAF**) is a framework for enterprise architecture that provides an approach for designing, planning, implementing, and governing an enterprise information technology architecture.

TOGAF is a high level approach to Enterprise design.

It is typically modeled at four levels:

- Business
- Application
- Data
- Technology.

TOGAF was developed starting 1995 by The Open Group, based on USA DoD's TAFIM.



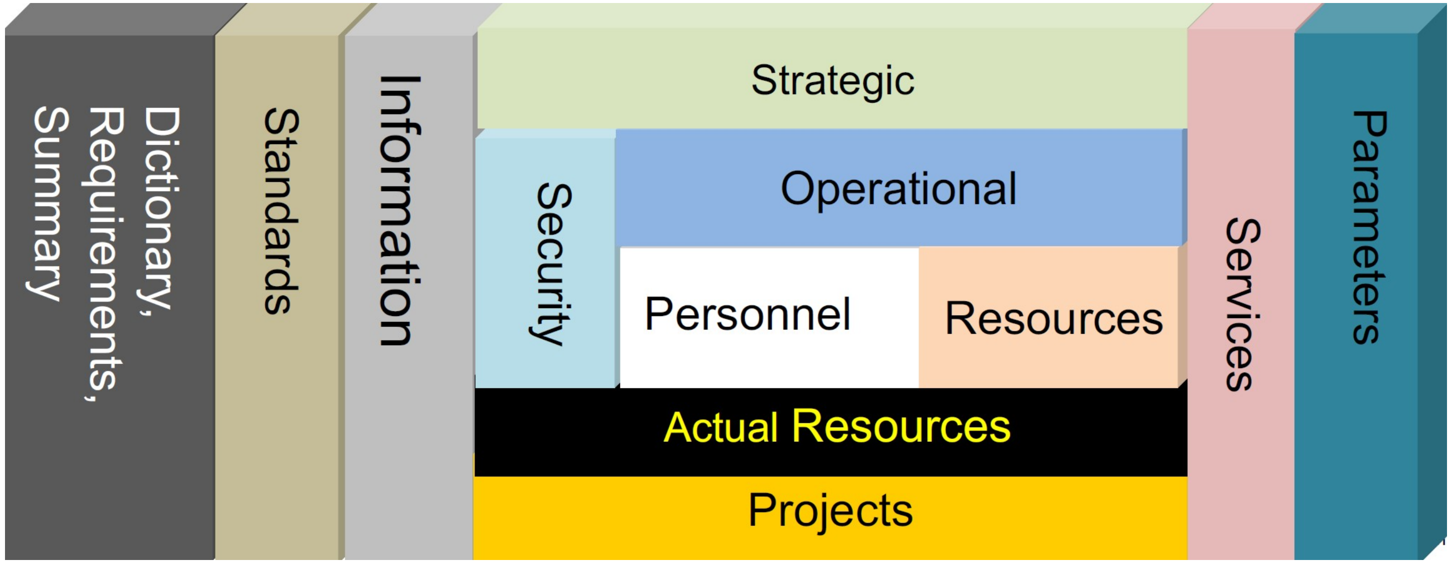
https://archimate.visual-paradigm.com/togaf-integrated-archimate/

https://www.erp-information.com/togaf-framework

UAF – Holistic model-based EA

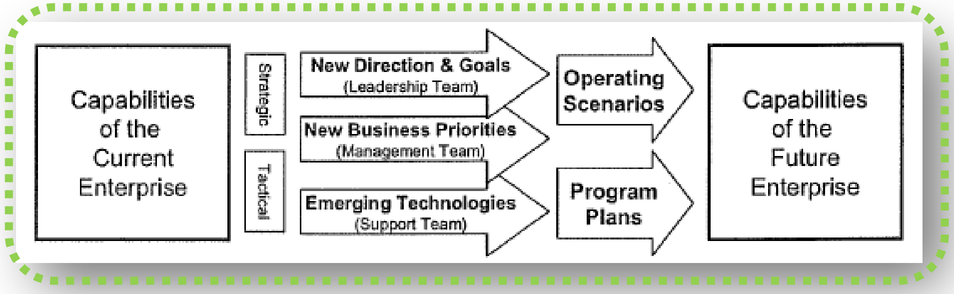
Unified Architecture Framework uses MBSE approaches and SysML for definition of its language UAFML, constructs and relationships as well as domains. Thanks to model based approach it enbales different disciplinary perspectives/views based on the UAF domains.

Vertical and Horizontal Domains



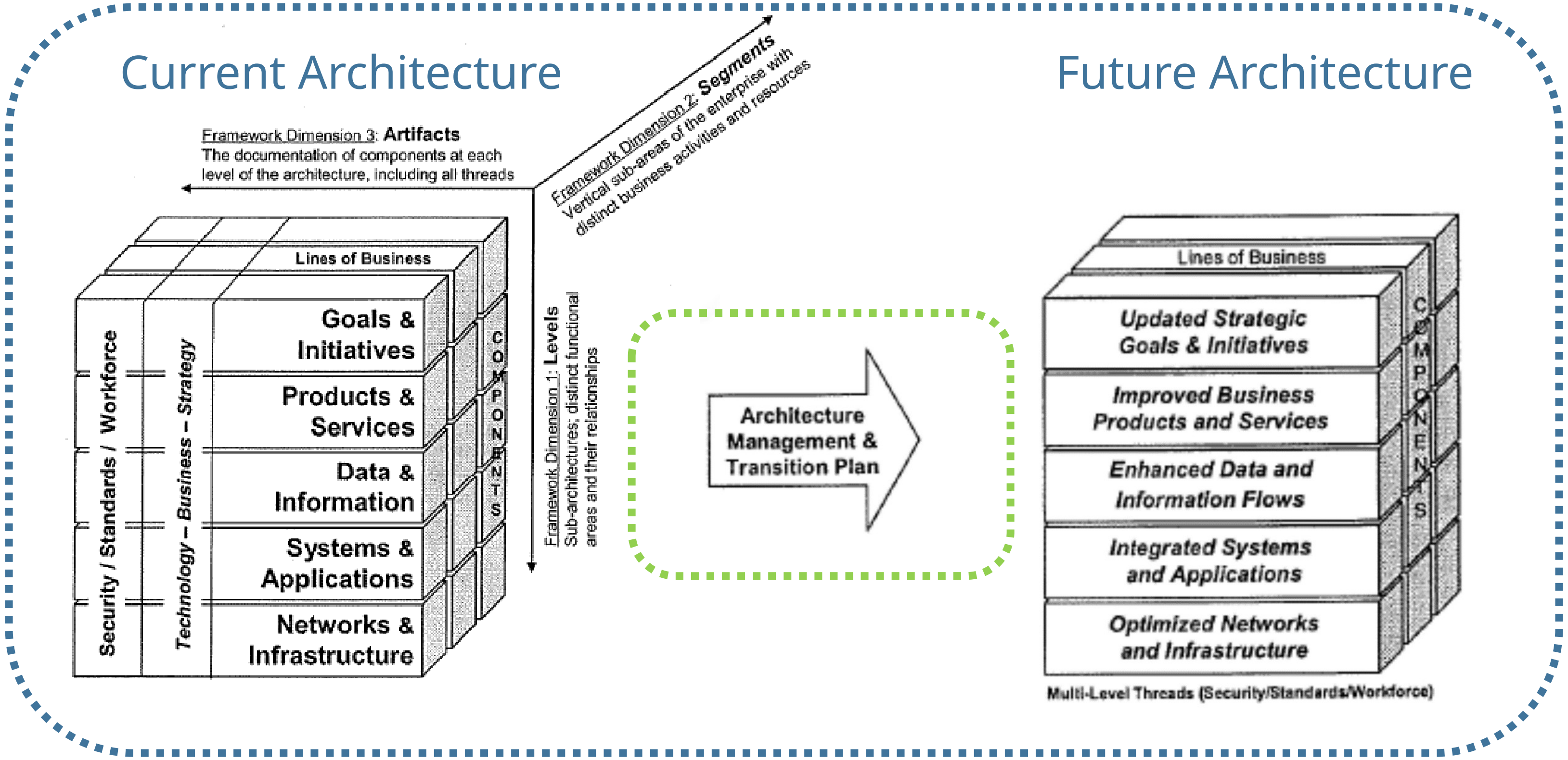
- Language
- Framework
- Transformation „guide“
- Domain perspectives
- Entire Enterprise Lifecycle support

https://www.omgwiki.org/uaf/doku.php



EA3 Cube

The EA3 is both EA framework and management approach to EA transformation



The EA3 framework is divided into portions known as **Lines of Business** (LOBs)

Each LOB is distinct, consisting of a complete **set of all levels of the architecture** framework

Bernard, 2012, An Introduction to Enterprise Architecture: Third Edition

EA3 Cube – EA Implementation

Phase I: EA Program Establishment

- **Step 1:** Establish the EA Management Program and identify a Chief Architect
  - *Identify stakeholders*
  - *Identify enterprise goals and gaps*
- **Step 2:** Establish an EA implementation methodology
- **Step 3:** Establish EA governance and links to other management processes
- **Step 4:** Develop an EA Communication Plan to gain stakeholder support
  - *EA organizational structure*

Phase II: EA Framework and Tool Selection

- **Step 5:** Select an EA documentation framework
- **Step 6:** Identify EA Lines of Business/Crosscuts and the order of their documentation
- **Step 7:** Identify the EA components to be documented framework-wide
- **Step 8:** Select documentation methods appropriate for the framework
- **Step 9:** Select software applications/tools to support automated EA documentation
- **Step 10:** Select and establish an on-line EA repository for documentation and analysis

Phase III: Documentation of the EA

- **Step 11:** Evaluate existing business and technology documentation for use in the EA
- **Step 12:** Document current views of existing EA components in all framework areas (levels/threads). Store artifacts in the on-line repository
- **Step 13:** Develop several future business/technology operating scenarios
- **Step 14:** Identify future planning assumptions for each future scenario
- **Step 15:** Use the scenarios and other program/staff input to drive the documentation of future EA components in all framework areas. Store artifacts in the on-line EA repository
- **Step 16:** Develop an EA Management Plan to sequence planned changes in the EA

Phase IV: Use and Maintain the EA

- **Step 17:** Use EA documentation to support planning/decision-making
- **Step 18:** Regularly update <u>current and future views of EA components</u>, and link information in the EA repository to create high-level and detailed “perspectives” of enterprise activities and resources in the current and future operating environments
- **Step 19:** Maintain an EA Repository and related modeling and analysis capabilities
- **Step 20:** Release annual updates to the EA Management Plan

Doule

Part 3

SOCIOTECHNICAL HSI AND TRL MODELS

3/ Enterprise Readiness

Following concept of Human-System Integration readiness developed by Boy & Doule states that success of the **human-socio-technical system** is based on **harmony of maturity** states, phasing and evolution of the fundamental constructs of the TOP model: **Technology, Organization, People** (Boy, 2021). The main premise of this concept is that if any TOP component is out of Readiness Level balance, the overall system of system, i.e. Enterprise, will not effectively achieve its intended goal. The readiness balance need to be determined by thorough scenario based modeling and simulation.

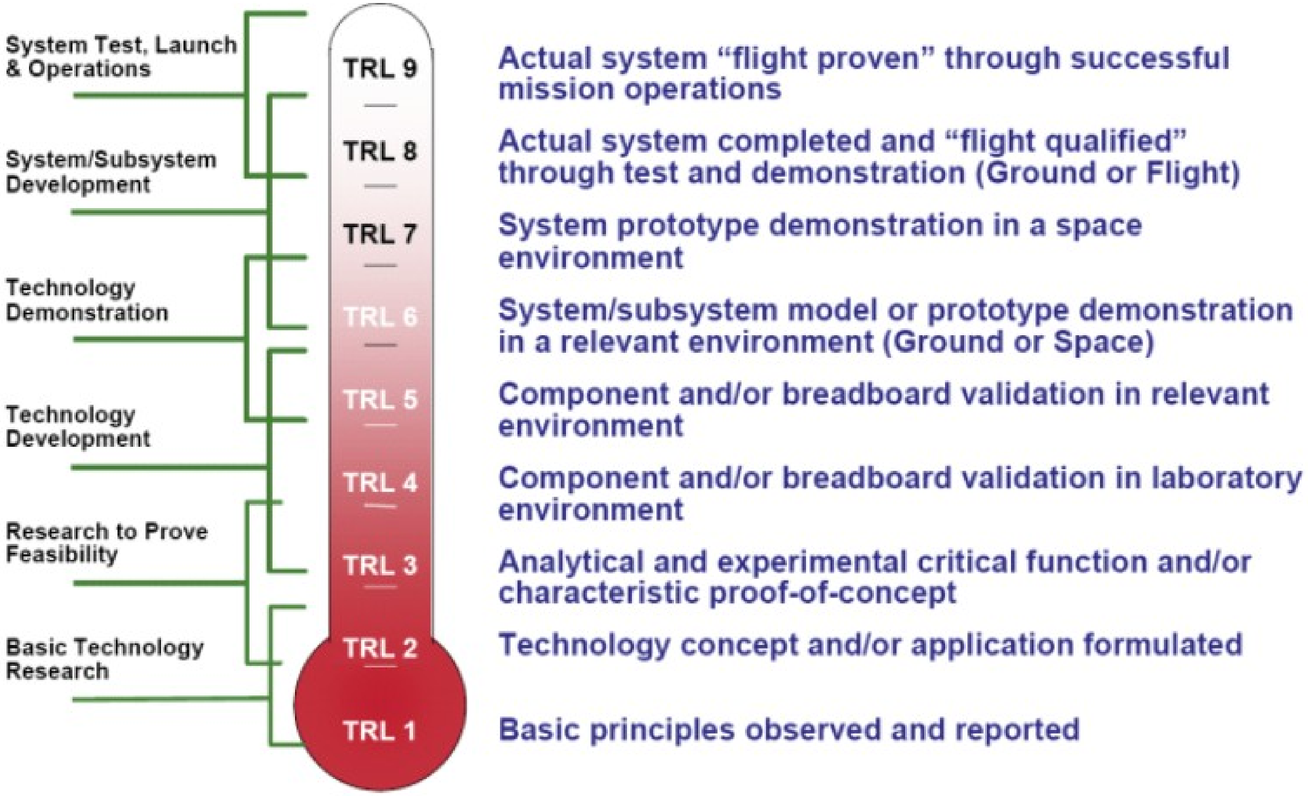
Technology RL: TRL was introduced in aerospace domain to indicate maturity of innovation and development of technical system.

Human RL: Recently it has been proposed by NASA that not only technology readiness is important for the Human-System operational success but also Human individual readiness.

Societal RL: G.A.Boy introduced in 2022 TRL of societal ergonomics as the last component of the TOP model which requires societal maturity to ensure success of individual and technical states and evolution

3/ TRL

Technology Readiness Levels (TRL) - a **systematic way to measure maturity through the project lifecycle**:



NASA

3/ HRL

Human Readiness Level (HRL) is a metric mimicking Technology Readiness Levels (TRL) both providing a **systematic way to measure progress through the project lifecycle**:

Level		Technology Readiness Level	Human Readiness Level
Production / Deployment	9	Operational use of deliverable	System successfully used in operations across the operational envelope with systematic monitoring of human-system performance
	8	Actual deliverable qualified through test and demonstration	Total human-system performance fully tested, validated, and approved in mission operations, using completed system hardware and software and representative users
	7	Final development version of the deliverable demonstrated in operational environment	Human systems design fully tested and verified in operational environment with system hardware and software and representative users
Technology Demonstration	6	Representative of the deliverable demonstrated in relevant environments	Human systems design fully matured as influenced by human performance analyses, metrics, prototyping, and high-fidelity simulations
	5	Key elements demonstrated in relevant environments	User evaluation of prototypes in mission-relevant simulations completed to inform design
	4	Key elements demonstrated in laboratory environment	Modeling, part-task testing, and trade studies of human systems design concepts completed
Research & Development	3	Concepts demonstrated analytically or experimentally	Requirements for supporting human performance established
	2	Concept and application formulated	Human-focused concept of operations defined and human performance design principles established
	1	Basic principles observed and reported	Relevant human capabilities, limitations, and basic human performance issues and risks identified

NASA/SP-20210010952, ***pg 55***

3/ ORL

Organizational (Society) Readiness Levels (ORL) are first introduce by G.A. Boy in an INCOSE awarded paper on Socioergonomics (INCOSE HSI 2021) in scope of system of system TOP model.

ORL-0	About first principles where potential organizational models are explored
ORL-1	Goal-oriented research that requires making choices from first principles to practical fully digital organizational setups
ORL-2	Proof of principle development and active R&D is started in a virtual environment
ORL-3	Virtual agile organizational prototype development and first HITLS (virtual HCD)
ORL-4	Proof of organizational concept development using concrete scenario-based design from fully virtual to more tangible environments
ORL-5	Assessing organization capability in terms of authority sharing (responsibility, account-ability, and control), trust, collaboration and coordination, for example
ORL-6	Real-world use-case tests in a wider variety of situations – tangibilization continues
ORL-7	Practical integration with respect to criteria such as safety, efficiency and comfort, at various levels of granularity of the organization – tangibilization continues
ORL-8	Readiness for effective implementation on a real site (fully tangible) based on personnel feedback for deployment approval
ORL-9	Deployment involving both personnel and real machines

NASA

Part 4

SPACE ENTERPRISE RELATED TECHNICAL SYSTEM ARCHITECTURE FRAMEWORKS

4/ Enterprise challenges

New entrants to space business are reported almost every day!

The challenges they face are of **technical complexities unknown to terrestrial businesses.**

- Technologies and Organizations are required to provide faster, cheaper, flexible access and services in space, robotics and automation is of a very high importance due to extremes and speeds the space environment deals with – which means, little space for improvisation, need for standardization on strategic, enterprise level.

I. CCSDS/ISO 311.0-M-1 “Reference Architecture for Space Data Systems (RASDS)”

II. NASA Handbook 1005 “Space Mission Architecture Framework Handbook for Uncrewed Space Missions”

III. ANSI/AIAA S-153-2021 “Human Spaceflight: Spacecraft Architecture and Systems Engineering Ontology”

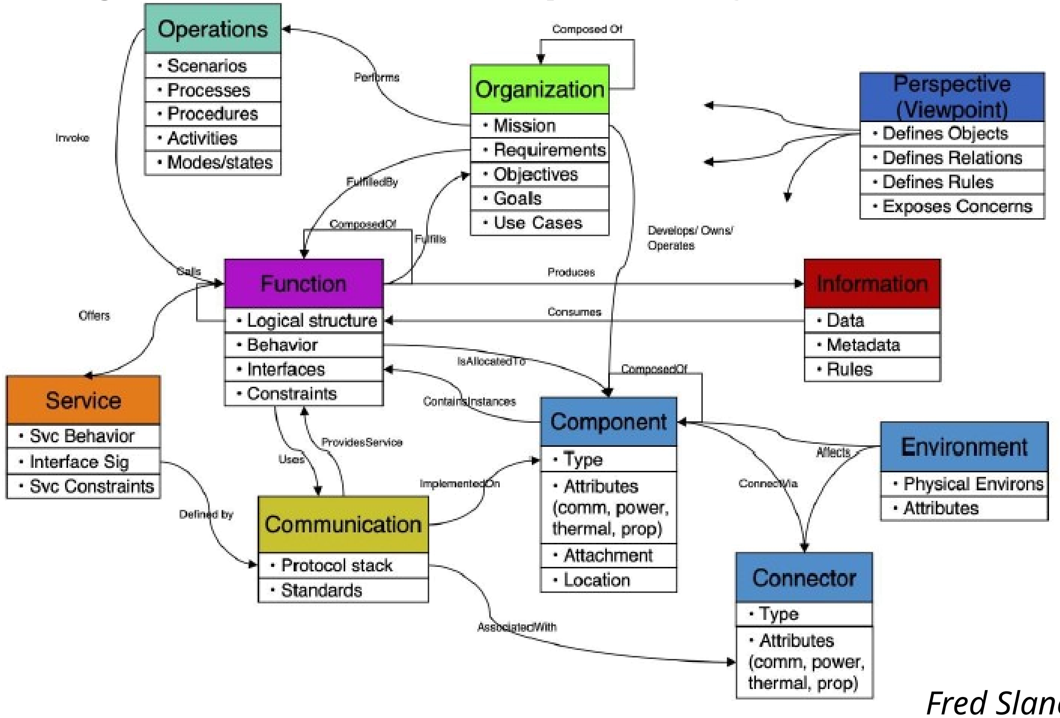
AIAA Slane et.al. Evolving Space Architecture – Opening the Door for the Space Industry

4/ I. RASDS

Reference Architecture for Space Data Systems (RASDS) is developed to provide viewpoints that may be used to describe complex space systems architectures. RASDS is offering a standard that could ease data management as an interoperability standard.

Top-level objects, their attributes in RASDS, illustrating how core objects from different Viewpoints are related:

1. Enterprise/Organization Viewpoint: objects are organizational elements, requirements, and use cases.
2. Functional Viewpoint: objects are abstract functions and data, and logical data exchanges.
3. Connectivity Viewpoint: objects are physical components and links and realized deployments of implemented functions.
4. Protocol Viewpoint: objects are protocols and protocol stacks, interface binding signatures, and end-to-end communications mechanisms.
5. Information Viewpoint: objects are information, data structures, syntax, and semantics.

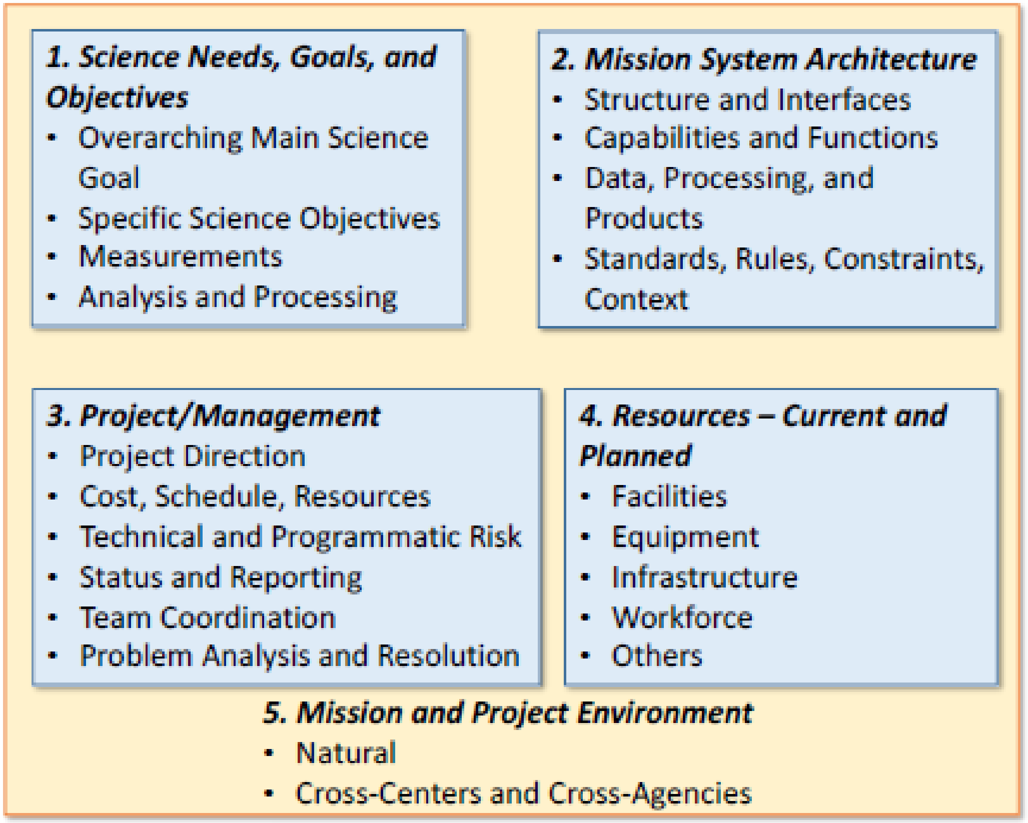


Fred Slane, 2021, SciTech

4/ II. SMAF

Space Mission Architecture Framework (SMAF) of NASA, is structured in terms of a set of viewpoints that capture diverse stakeholder perspectives, needs, and concerns and to be realized on Mission Architecture level in MBSE form as an EA.

The enterprise viewpoint addresses mission architecture (2) from the perspective of the Space <u>Center</u> and <u>Agency</u> stakeholders. The included work products link the project to higher level goals and objectives of strategic and program plans, as well as to overarching drivers of NASA science efforts such as decadal surveys.



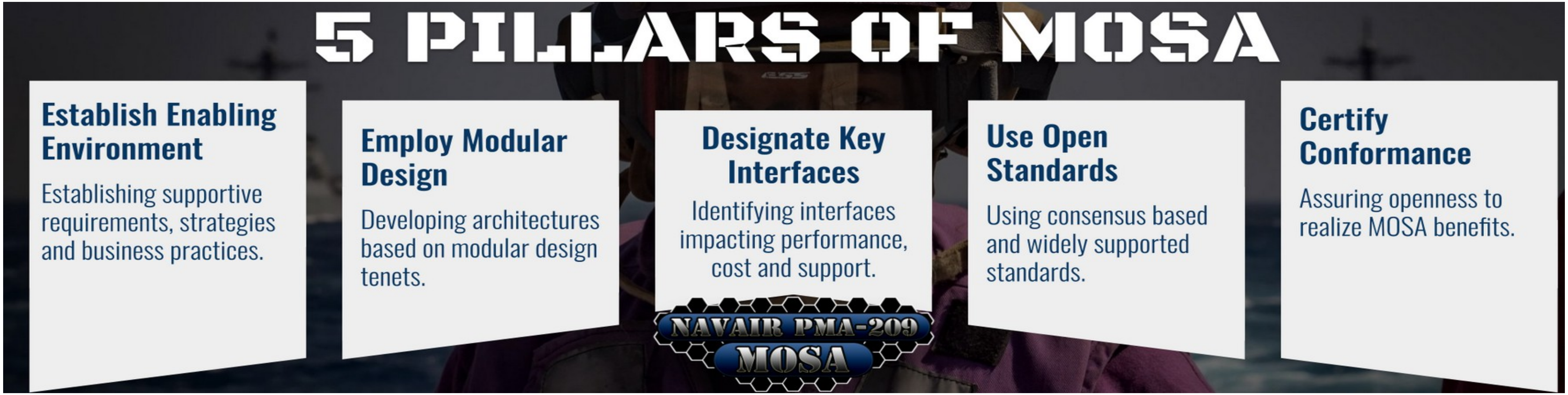
ANSI-AIAA S-153-2020

4/ III. MOSA

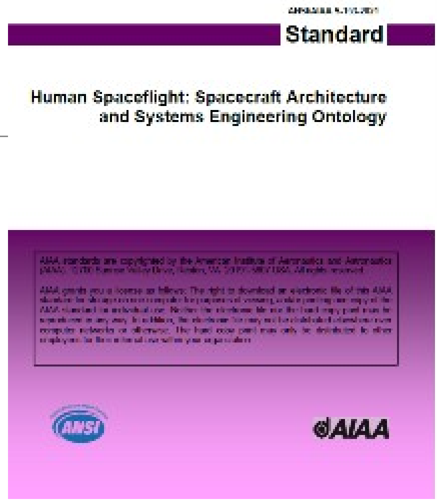
https://www.navair.navy.mil/MOSA

Industry grade meta-standard for Modular Architecture Frameworks

Modular Open Systems Approach (MOSA) is an integrated business and technical strategy designed to achieve competitive and affordable acquisition and sustainment over the system life cycle via the implementation of open system and or open architectures standards approved by the DoD



4/ III. HSI – ANSI S-153-2021



Architecture is a mental construct consisting of fundamental concepts about the properties of a system, the system's environment, the relationships therein, and principles of its design and evolution. Architecture is presented via **Architecture Description** by the involved stakeholders via SysML, CAD, sketches etc..

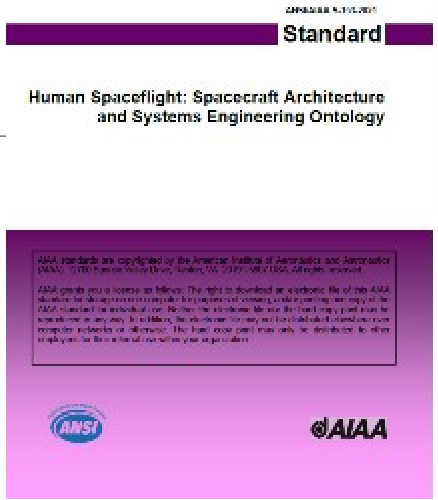
ARCHITECTURE CLASSIFICATION – Logical Classification Flow

1. Fundamental Architecture → **2. Enterprise Architecture** → **3. Operational Architecture**

4. System Architecture → **5. Technical Architecture**

ANSI-AIAA S-153-2020

4/ HSI Architecture – ANSI/AIAA S-153-2021



ARCHITECTURE CLASSIFICATION according to application

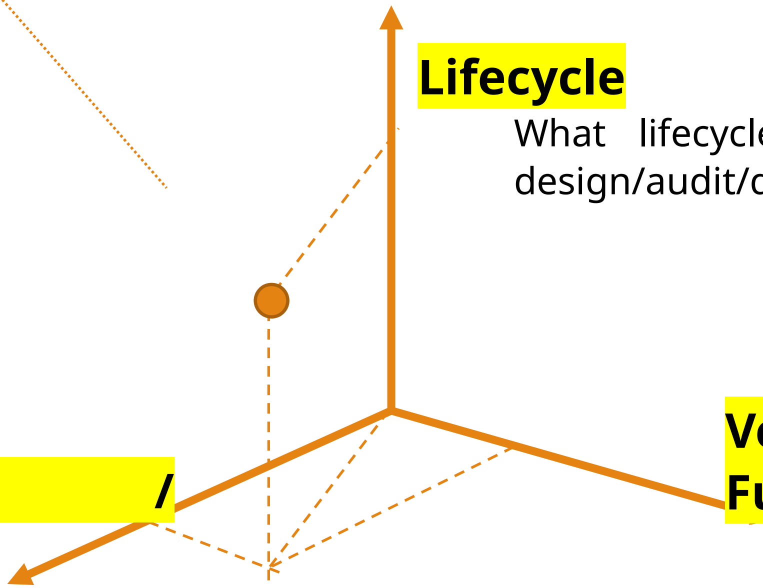
#	Category	Description
1	Space transportation	Primary function of this system is to transport Crew or Spaceflight Participants (SFP) from point A to point B
2	Space exploration	Primary function of this system is reconnaissance, discovery, simulation and research
3	Space tourism and commercialization	Primary function of this system is one of the following: space sightseeing, spaceflight experience or commercial non-research purposes
4	Resources mining, processing and utilization	Spacecraft belonging to this category performs one or more of the following or related functions: search or collection of resources, refining and application of space resources, in-situ resource utilization (ISRU)
5	Construction and deployment	Spacecraft belonging to this category performs one or more of the following functions: construction, self-construction or assembly, deployment of prefabricated structures
6	Human Health & Performance	Systems for containment, support, stabilization and treatment of crew or spaceflight participants
7	Government applications	A system developed, deployed or operated for a governmental purpose including navigation, communication, transportation, exploration, resource mining construction, medical and military applications of spacecraft of a government
8	Emergency response and maintenance	A system developed, deployed or operated for an emergency or maintenance purposes

ANSI-AIAA S-153-2020

4/ HSI Architecture – ANSI/AIAA S-153-2021

Example: Medical facility on orbit **–**

S-153 structures the vessel types. Future versions of S-153 will also provide list of relevant standards and guides



What lifecycle phase do I need to design/audit/develop? *(Select one)*

Where is the system located, what is the primary destination mission? *(Select one)*

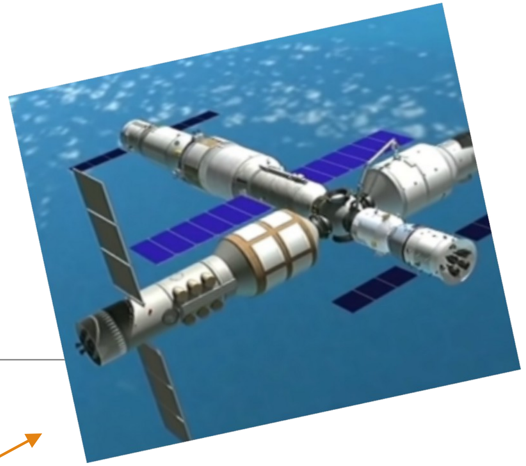
ANSI-AIAA S-153-2020

Part 5

GENERAL TRANSFORMATION CHALLENGES – HSI PERSPECTIVE

5/ Challenges

21st century microgravity orbital station



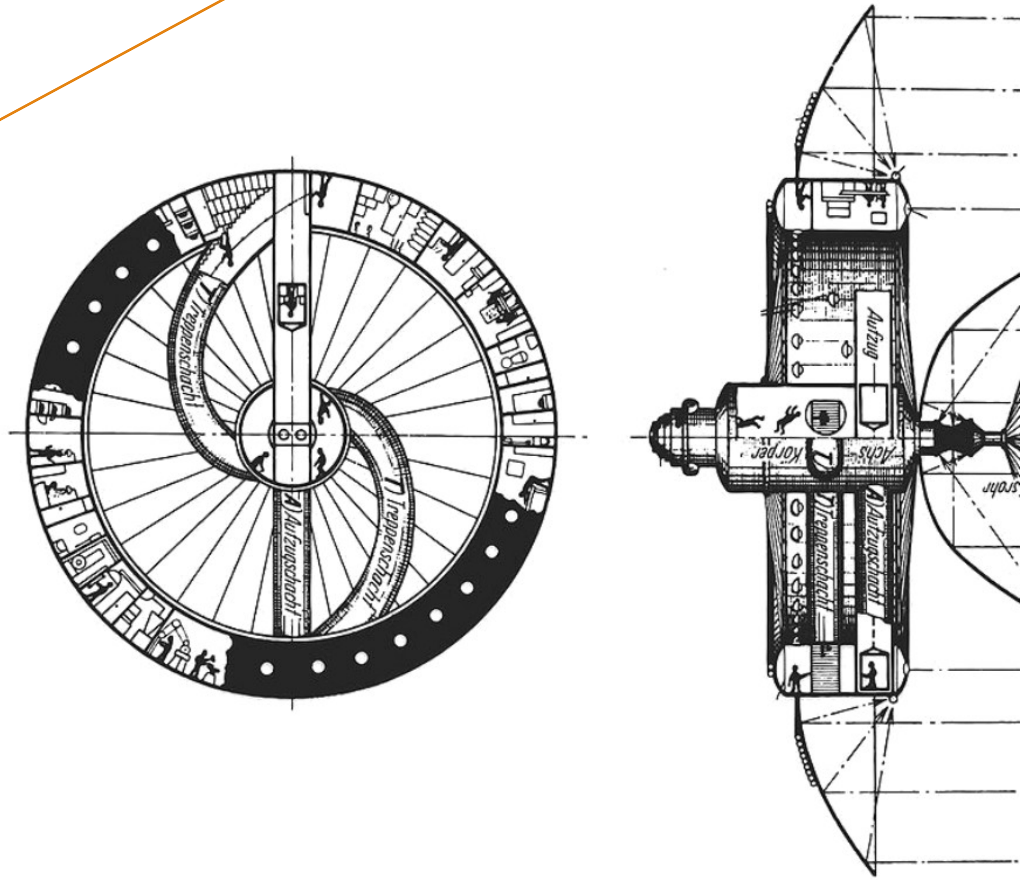
Enterprise **goals** and decisions: Context – Establishment of orbital space station

Nominal habitation is not possible in microgravity, there are many health and operation risks!

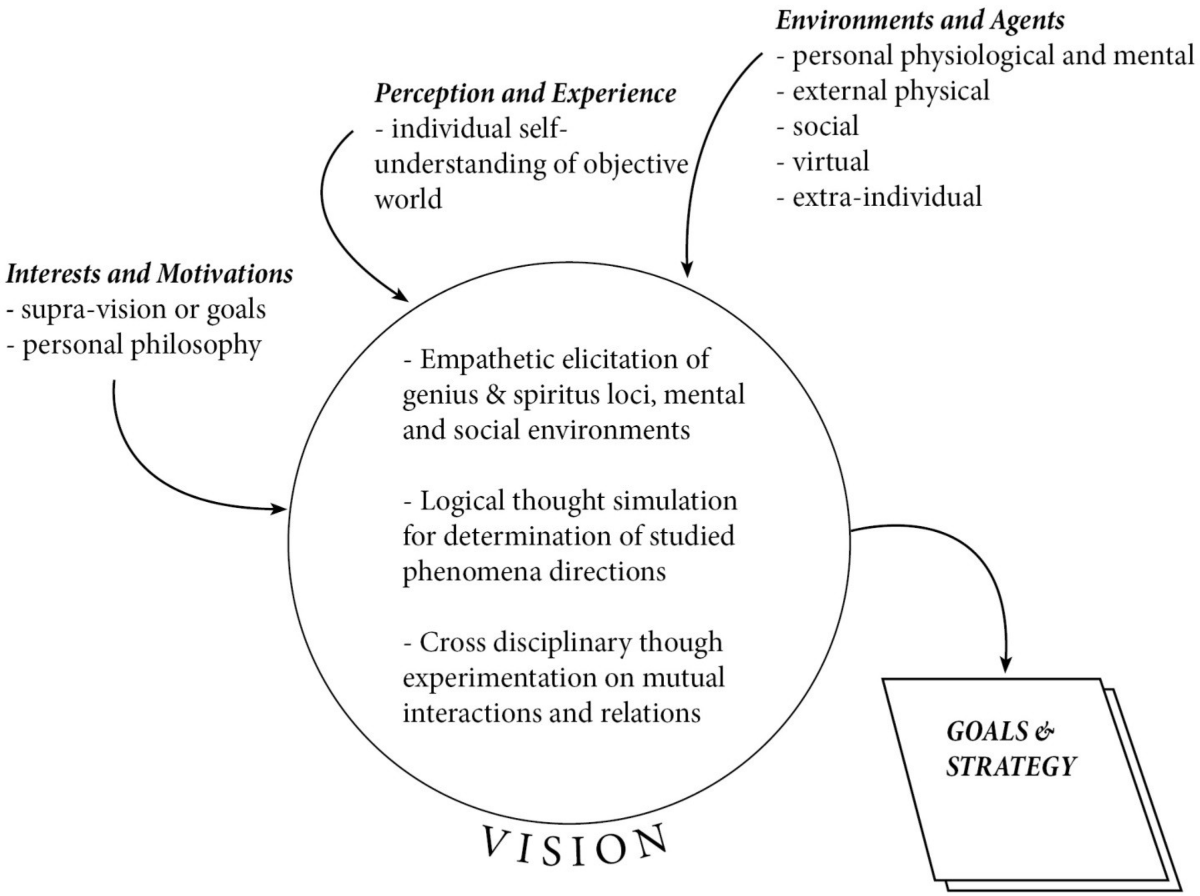
Nonetheless the international community decided 100% reliance on human adaptation to extreme environment and build microgravity orbital station instead of artificial gravity rotating wheel station.

Why? Is that a good enterprise approach?

Noordnung – Her
Potočnik 19ct firs
artificial gravity
station engineerir
concept



5/ Goals and vision influences distortion… *values context*



Common language – semiotics is still the major problem of interdisciplinary communication. Engineering culture of each domain uses different language and perceives scope of work in different manner.

Common thought framework – while software engineer works efficiently with backlog, designer requires interdisciplinary input that sometimes can't be written in the backlog and that stems out of brainstorming as an emergent requirement that can be critical to the system design.

Domain respect – experts, specialists often tend to prefer domain they are involved in and ignore or even disrespect other domains. This preference is cause of many personal and interdisciplinary clashes and one of the main problems in interdisciplinary system work. Avoidance is directly related to thorough interdisciplinary education. Here we are talking about generations of education that may take long time to implement.

Doule, 2015, System architecture complexity in definition of human spaceflight simulators, analogs and human space flight process dependent on mission goals and strategy, AIAA Space Forum 2015, Pasadena, USA August 31 - September 2, USA

5/ Goals and vision influences distortion… values

Your challenge will always be wrapped around four types of values and how decision makers prioritizes them:

Doule, 2015, System architecture complexity in definition of human spaceflight simulators, analogs and human space flight process dependent on mission goals and strategy, AIAA Space Forum 2015, Pasadena, USA August 31 - September 2, USA

Y%

Values

… and their objective or purposeful unawareness

…often unpronounced due to unjustified fear of loss...

X%

Z%

V%

Such behavior causes major damage to your and client business...

5/ Challenges (non-IT)

Risks induced by improper enterprise HSI – non-IT risks

Digital Transformation
- Framework
  1. Current
  2. Future
  3. Transformation

A - Political bias
- Products or solutions are **artificially stimulated** – no real “quality by market audit” – quick to fail, or fail for long time risk
- Diminished competence over subjective preference in fulfillment of corporate **roles**
- **Personal** gains **vs. corporate** gains by corporate SMEs (lack of leadership competence)

B - Leadership oversight
- Lack of insight in SME processes
- Lack of understanding of current vs future solutions
- Lack of competence (political role only)
- Ignorance to transdisciplinary problems
- EA ignorance or incapability to EA comprehension
- Difficulty with abstract modeling
- Difficulty with definition/understanding of scope or work break down
- Underestimating research and adaptation efforts
- Difficulty with direct simple tasking
- Personal gains vs corporate gains by corporate SMEs (lack of leadership competence)
- Lack of understanding of capabilities of own team

5/ Challenges (non-IT)

Risks induced by improper enterprise HSI – non-IT risks

Digital Transformation
- Framework
  1. Current
  2. Future
  3. Transformation

C - Cultural bias
- "We have done this since Apollo and it always worked" attitude
- Resistance to change due to static, passive management over long period of time
- Finance vs product quality bias
- Lack and low interest in training to keep up with socio-tech evolution

D - Transformation related hidden conscious and subconscious malicious behavior (HSI risks)
- Loss of data
- Document based rather than Model Based EA
  - No data traceability due to poor documentation
  - No SSOT
  - Data retention
- Knowledge retention
- Tool and method bias
- Lack of leadership competence
- Lack of general transformation experience < GLOBAL PROBLEM
- Lack of sensitivity or capability to potential human behavior i.e., Human System Integration modeling and projecting
- **Low capacity for Design Thinking (Fear of Change)**

5/ Challenges (non-IT)

Risks induced by improper enterprise HSI – non-IT risks

Transformation
- Framework
  1. Current
  2. Future
  3. Transformation

$3.1 trillion a year of the cost overrun due to poor quality data where **human error** contributed as financial institutions handle more transactions every day (according to IBM: HBR.org/2016/09/bad-data-cost-the-u-s-3-trillion-per-year).

- **Bad planning** - labor budget overrun
- **Bad use of data** - during work process i.e., time.
  - Prolong the nominal data processing
  - Aggravated customers
  - Resending corrections at additional cost
  - Time consuming correction of errors
  - Propagated errors, chain of errors resolution or mitigation
  - Reimbursements
  - Reputation and Customer losses

Operation of the **Department for correction of Human or other data error**

Human Error has many forms

Can be mitigated by modeling and simulation

Scenario Based Design, Design Thinking, HITLS!

5/ Challenges (non-IT)

Risks induced by improper enterprise HSI – non-IT risks

REMEMBER WHO STAKEHOLDERS ARE:

- Recall that an EA stakeholder is defined to be anyone who will be affected by the EA program (this will most likely be the majority of the people within the enterprise)

- Stakeholders are the ones most likely to resist change

- By getting them **involved as early** in the EA program as possible, they will feel that they are a part of the program

- Communicating EA program activities includes the publishing of formal documents such as the EA Program Communication Plan and the EA Management Plan, and also notifications of updates to EA views and components

- Allowing stakeholders to voice their opinions regarding EA planning and decision-making increases the buy-in of the stakeholders since they see themselves as having their concerns and opinions heard and included

- Managing the expectation of the stakeholders means making sure that they understand what the EA program can, and cannot, do, and to unreasonable expectations

Part 6

MINIPROJECT

- IA CONTEXT ENGINEERING : **ENTIRE PRESENTATION MUST NOT BE UPLOADED, TEXT FROM PRESENTATION AND GENERATIVE IA IS PERMITTED**

- PROMPT ENGINEERING: **TEXT FROM PRESENTATION CAN BE USED**

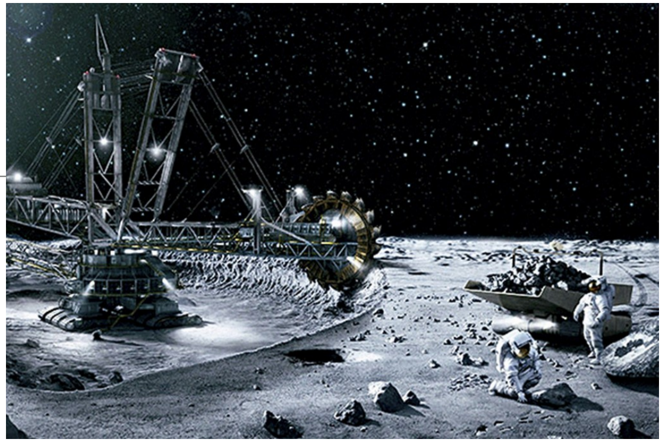
- LLM, AGENT, MULTI-AGENT AI ARE PERMITTED

- GENERAL AI, SUPER AI, NON PROGRAM ENROLLED THIRD PARTY HUMAN AGENTS, ONLINE HELP IS NOT PERMITTED! > IMMEDIATE FAIL

MINIPROJECT

6/ Moon Resources

https://www.wired.co.uk/article/space-mining-a-reality-in-2016



Successful terrestrial business intends to approach new space market as they foresee significant potential profit. The moon is not constrained by any environmental or legal rules except “Planetary Protection” guidelines and “Space Treaty” rules. The corporation indents to establish a branch “Moon Services and Resources ” which will invest and develop in space infrastructure (e.g., mining infrastructure), and will target moon as the primary resource target.

French corporation will have to establish a partner corporation in USA as that is the only country with heavy lift launchers and space exploitation legal framework. Your task is to select existing corporation and help it to expand their business in space.

1. What transformation components and challenges the French company would have to address?
2. How would you mitigate identified risks?
3. Can you envision business drivers, needs, subjects of transformation, what changes and new tools are needed?

4. Analyze current business (terrestrial). Propose expansion to space identify existing and new operations, CONOPS, major Use Cases, Business Case (expansion justification) + on slide 7.
5. Propose expansion and transformation Roadmap.

6. Use AI for research, formulation and business engineering. (e.g., GPT for business, Claude for engineering, Perplexity for references) **and provide a reusable prompts and their sequence(or just one refined prompt) for all parts of the proposal**

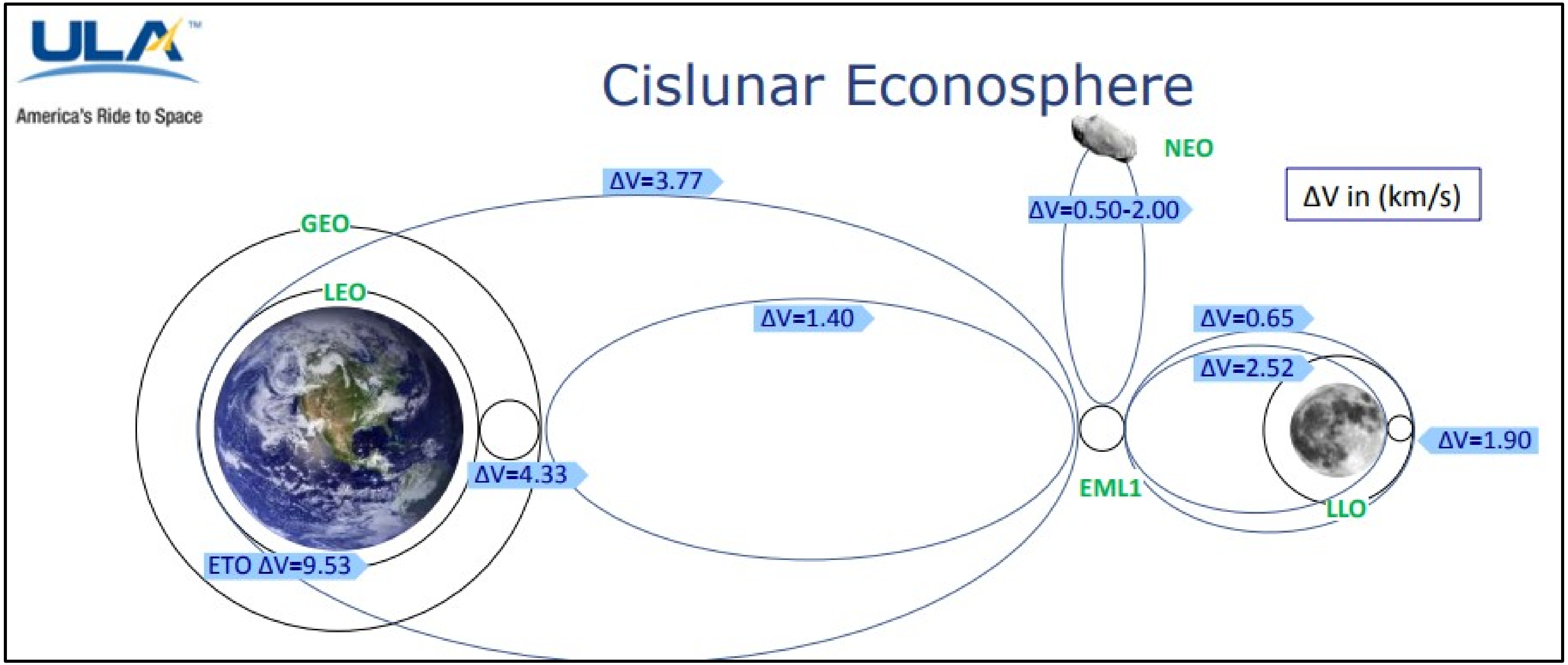
Grade:

Q1-3: 25% (qualitative review – business success confidence)

Q4-5: 25% (qualitative review – business success justification)

Q6: 50% (prompt execution % match)

6/ Moon Resources



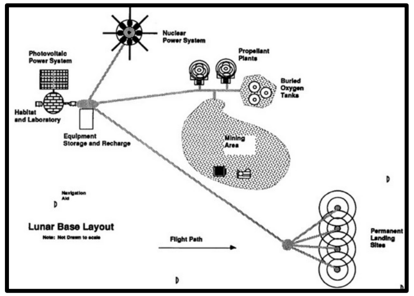
Source: ULA

Launcher	Lifting Capability [m. ton] (LEO)	Production Capability [launches per year]
SLS Block 1B (2021-2023)	105	One per year (Total: Cis-Lunar: Up to 2; Mars: up to 3)
SLS Block 2 (>2028)	130	

6/ Moon Resources

Design Parameters and Mass Approximations

LSS - Lunar Surface Settlement

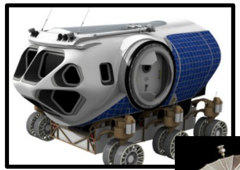


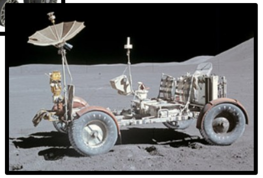
LSS Production Requirements (Min)	
Total Mass of Fuel to be produced on Mars	1,040,000 kg
LSS Supporting Systems Mass	
Lunar Surface-LEO Fuel delivery infrastructure	175,000 kg
ISRU System	58,700 kg
Fission Power System	200,000 kg
Total Mass to Lunar Surface (From Earth)	**434,000 kg**

LSS Habitable Systems Requirements	
Crew Size	30
Habitable Volume	947 m^3
LSS Habitable Systems Mass	
Habitable Modules Mass	379,000 kg
Laboratory Mass	18,900 kg
Storage Mass	18,900 kg
Medical/Decontamination Mass	11,900 kg
Total Mass to Lunar Surface (From Earth)	**428,700 kg**

LSM - Lunar Surface Mobility

- 7.070 kg





LSS Production Requirements (Max)	
Total Mass of Fuel to be produced on Mars	2,430,000 kg
LSS Supporting Systems Mass	
Lunar Surface-LEO Fuel delivery infrastructure	410,000 kg
ISRU System	138,000 kg
Fission Power System	500,000 kg
Total Mass to Lunar Surface (From Earth)	**1,048,000 kg**