Skoltech
Skolkovo Institute of Science and Technology

SIRG
Strategic Innovation Research Group

Concurrent Engineering Design Laboratory Overview

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The Problem

Problem: Design Complex Engineering Systems

- Composed by multiple Subsystems referring to different Disciplines

Satellite Mission Example:

- **Design and Development:**
  - **Flight Segment:** Payload, Orbit, Thermal, Structure, Power, TT&C, Avionics, Configuration, AOCS, Mechanisms.
  - **Ground Segment:** Flight Operations, Data Acquisition, Data Processing, Data Archiving, Mission Planning, Mission Coordination, Quality Control.
- **Program Management**
  - Cost, Schedule, Risk.
  - Customers, Prime Contractors, Subcontractors.
- **Stakeholders Needs**

How to organize the development process for a multidisciplinary complex system designed by multiple organizations?

Where is CE Design in the lifecycle?

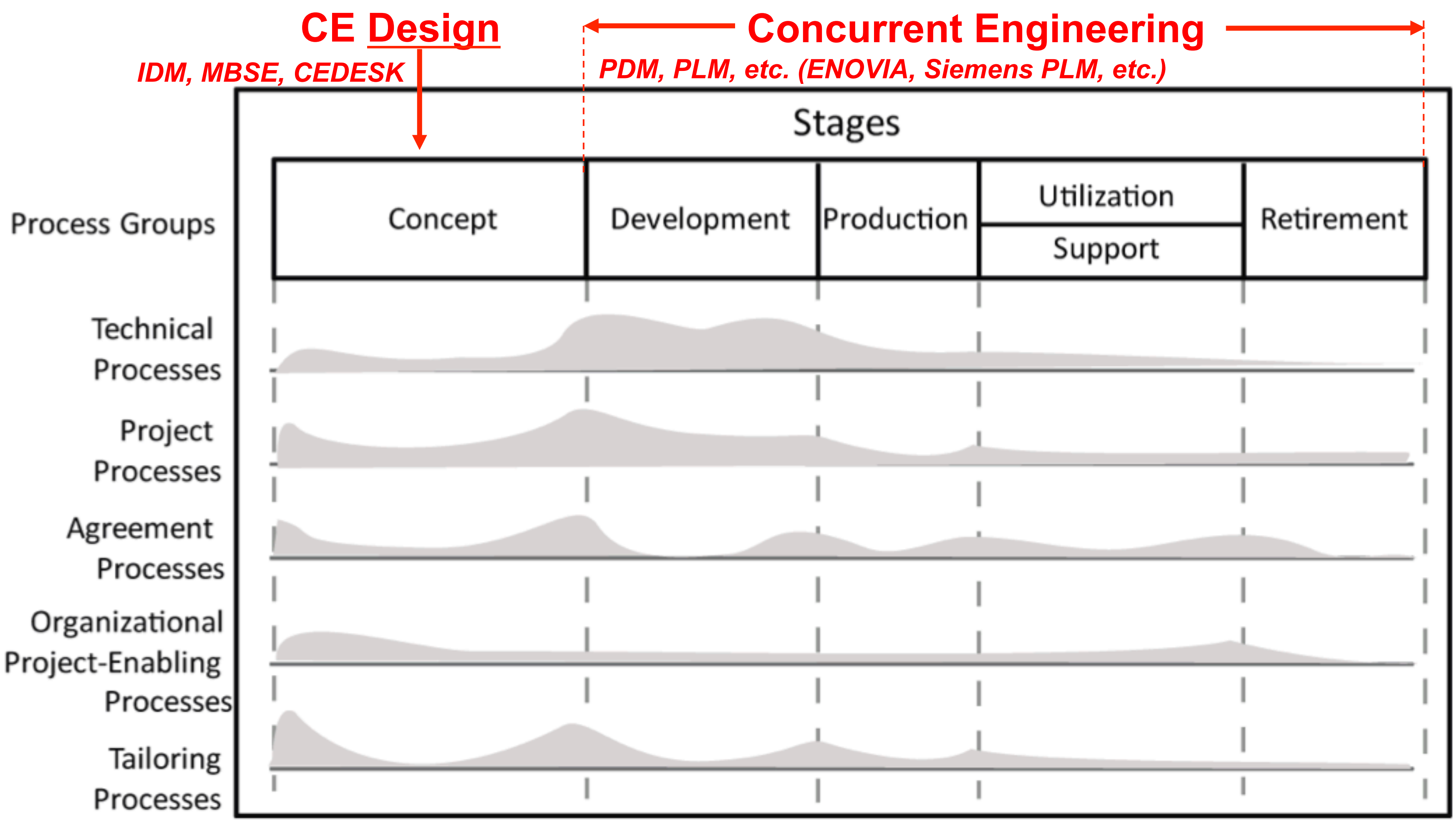
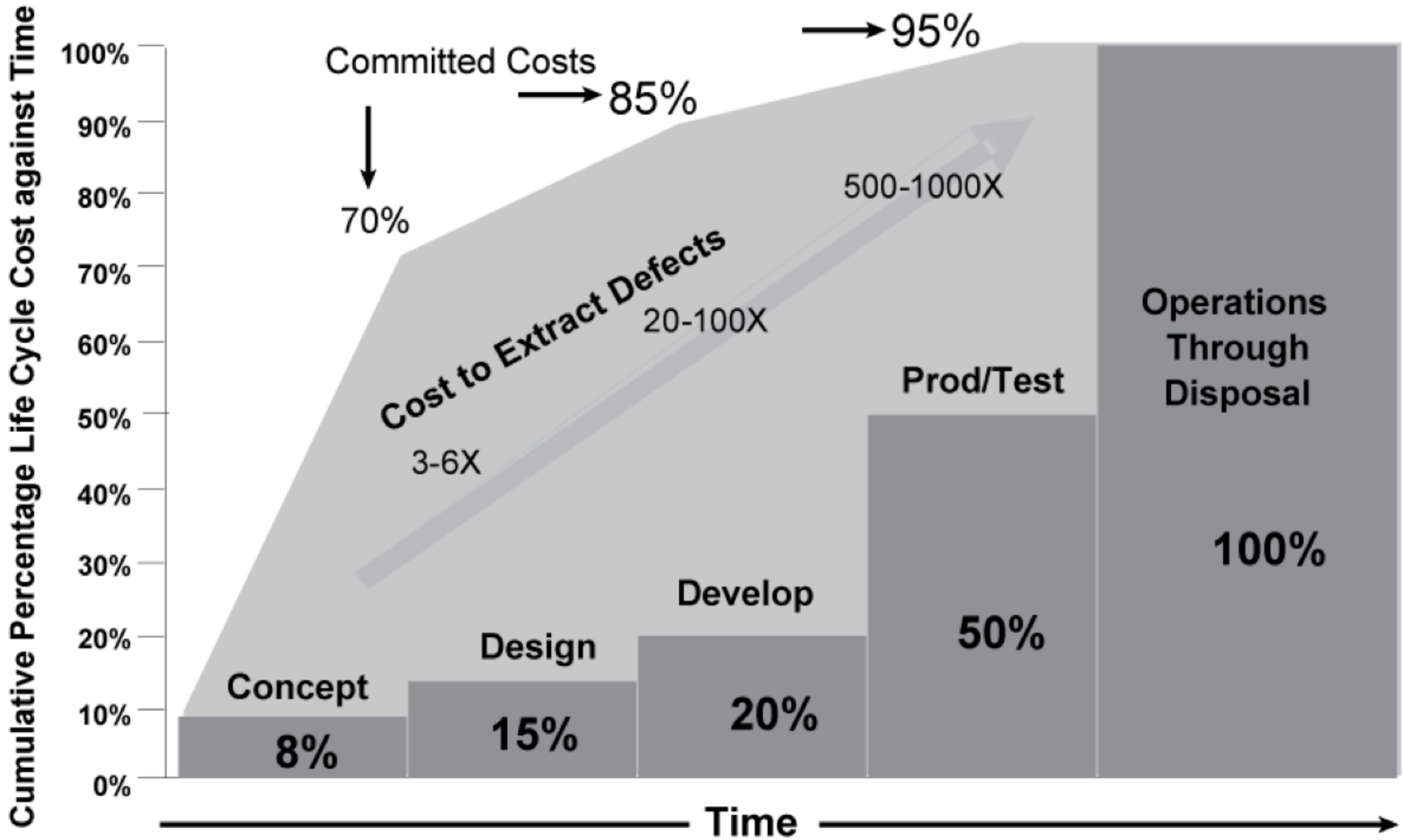


Figure 3-2 SE level of effort across life-cycle stages[7]

(image source: INCOSE)

Why is CE <u>Design</u> important?



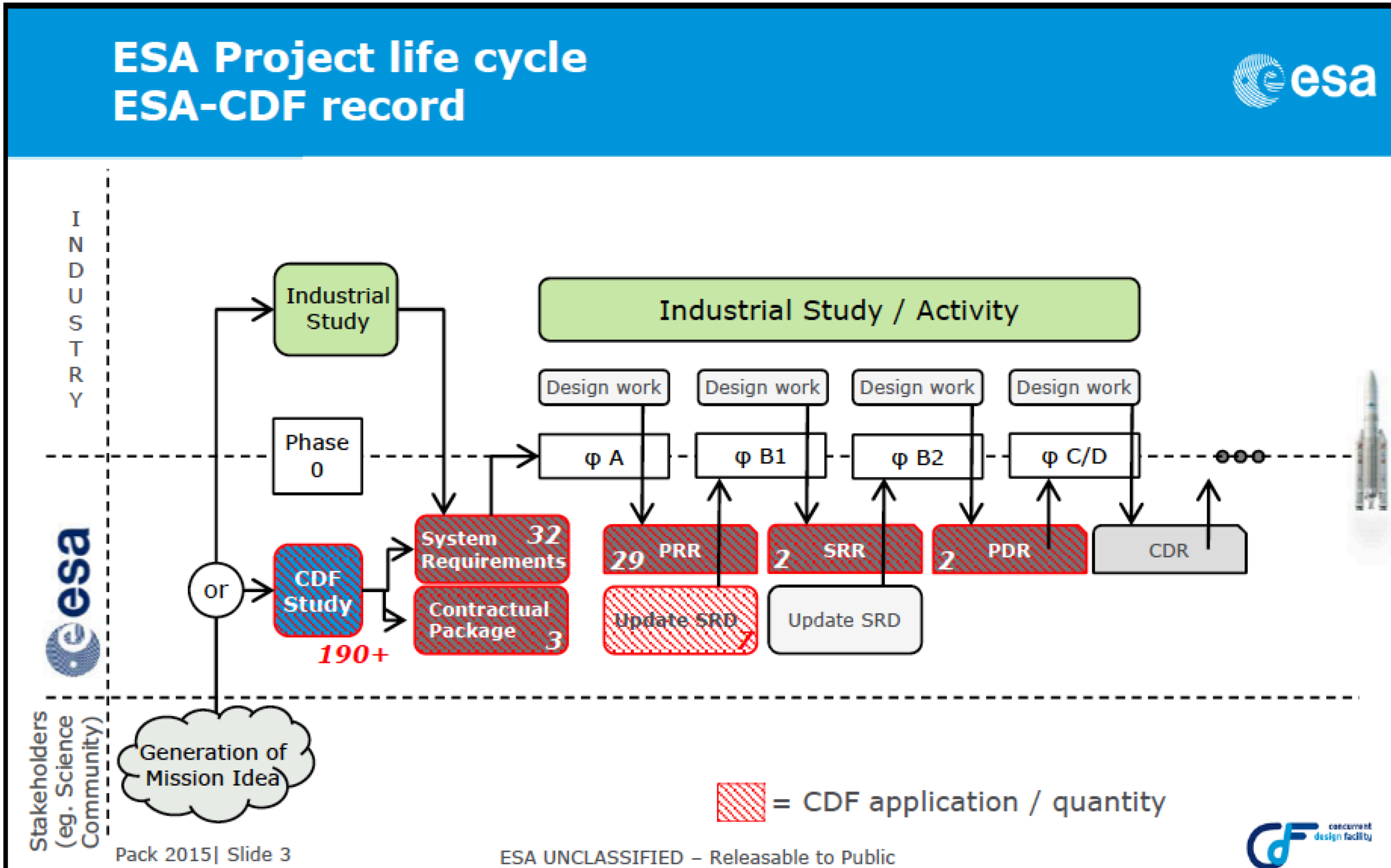
(image source: INCOSE)

Concurrent Engineering - definitions

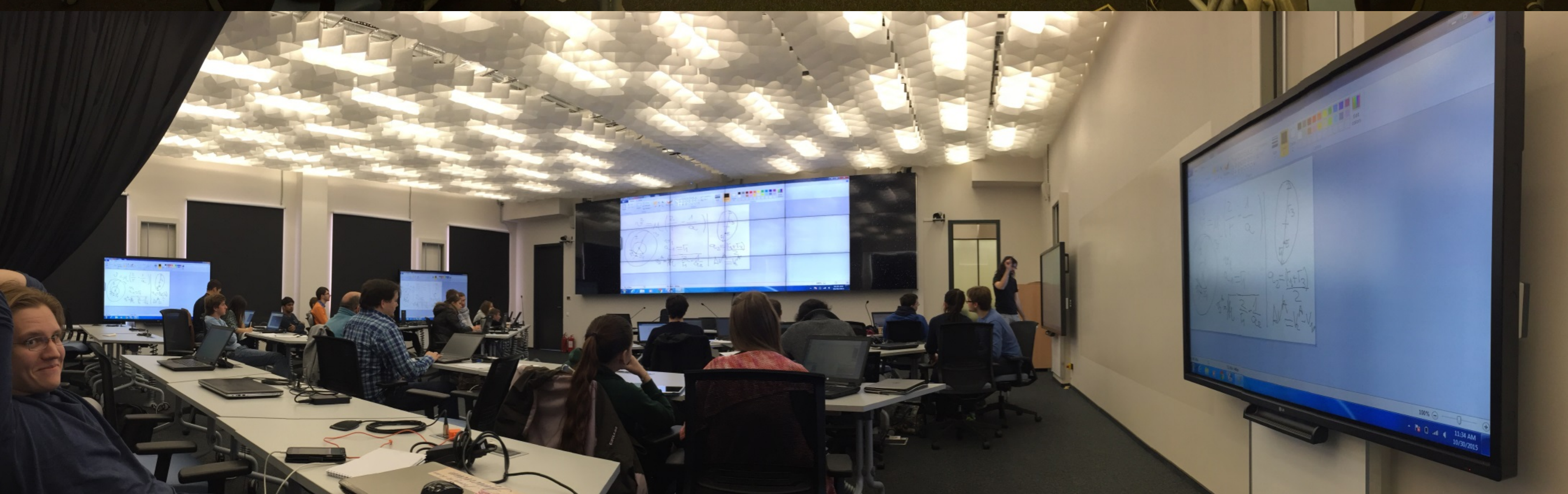
"*Concurrent Engineering (CE) is a systematic approach to integrated product development that emphasizes the response to customer expectations. It embodies team values of co-operation, trust and sharing in such a manner that decision making is by consensus, involving all perspectives in parallel, from the beginning of the product life cycle*" (ESA CDF)

"*Concurrent Engineering is a systematic approach to the integrated, concurrent design of products and their related processes, including, manufacturing and support. This approach is intended to cause the developers from the very outset to consider all elements of the product life cycle, from conception to disposal, including quality, cost, schedule, and user requirements.*" (Winner 1988)

Project Lifecycle - ESA CDF Example



CONCURRENT ENGINEERING DESIGN LABORATORY



Concurrent Engineering Design Lab.

To provide a concurrent engineering environment at Skoltech that is able to support conceptual design studies, and systems architecture research and related education activities.

A "First" in the Russian Federation.

Active in five high priority technology sectors: Energy, IT, Biomed, Manufacturing, Space.

Open to collaboration in Russia and abroad.

Experimenting with novel methodologies and tools that to date are not fully developed in any concurrent engineering center in the world.

Concurrent Engineering Facilities Worldwide – Space (top 6 CDFs in the world)

ESA CDF

DLR CDF

NASA GSFC Mission Design Center

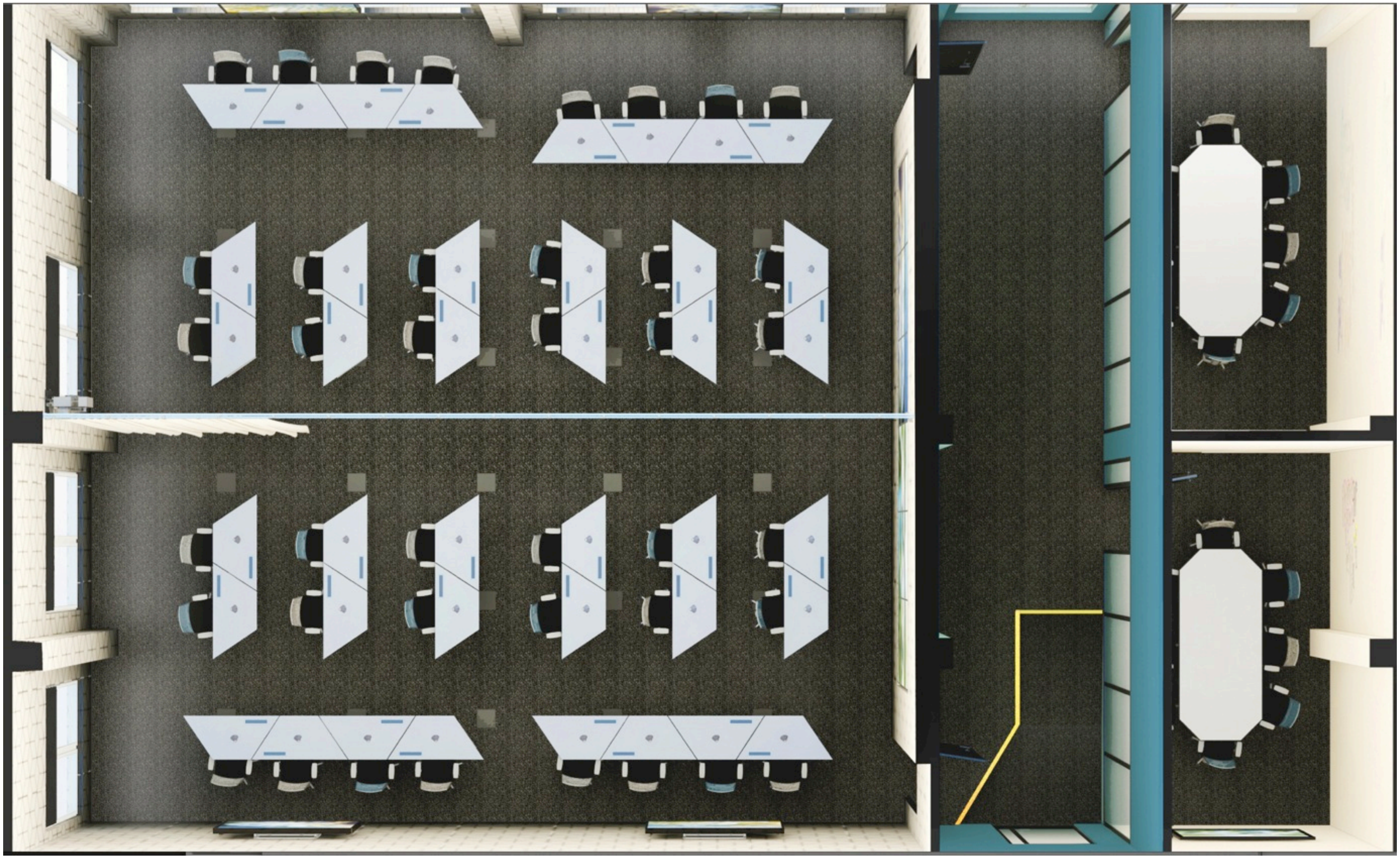
RAL Space CDF

NASA JPL Team-X / A-Team

CNES Centre d'Ingénierie Concourante

SOME NUMBERS OF CEDL

Q3 2015	**initial operating capability**
40+18	**design seats**
310	**m^2 laboratory**
1	**main design room (140 m^2)**
2	**breakout rooms (40 m^2)**



Apr 2016


Communications
Inputs
Shared
Space Segment
Mission Top Level requirements


Spacecraft power budget
Communications
Mission Top Level requirements


Optical payload design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CEDL SOFTWARE SUITE

Software Name	Purpose
Adobe Master Collection CS6 6.0 MLP	Image manipulation
Autodesk 3DS MAX	3D video rendering
Catia V5 Academic license	CAD 3D
Citrix XenDesktop Enterprise	Software virtualization
DecisionTools Suite	Decision making support tools
ESATAN-RADIATIVE + ThermXL	Thermal analysis
ESATAN-TMS	Thermal analysis
Fluent	CDF
MagicDraw and SysML licences	SysML
MSC Nastran LS Productivity Bundle	FEM
Orcad PCB Designer Pro + Pspice	PCB Prototyping
PHX ModelCenter	Multidisciplinary optimization
Solidworks Premium 2014	CAD 3D
Solidworks Education Campus License 2014	CAD 3D
Space Point Components Database	Space components DB
STK + SatPro + Coverage	Mission analysis
STK educational license	Mission analysis
TreeAge Pro	Decision making support tool
CEDESK	CE Data Exchange **(SIRG proprietary)**
Cisco Webex	Teleconferencing
Excel + MS Office	General purpose
MATLAB	General purpose / scientific calculations

CONCURRENT VS COLLABORATIVE ENGINEERING

Are collaborative and concurrent engineering the same thing?

No. They refer to different, complementary approaches.

While a concurrent engineering process is by nature collaborative, a collaborative engineering process is not necessarily concurrent.

(Yet, some authors in the past defined collaborative engineering as an evolution of concurrent engineering*)

LESSONS LEARNT IN THE DEVELOPMENT OF A CONCURRENT ENGINEERING INFRASTRUCTURE

WHAT DID WORK IN OUR PROJECT

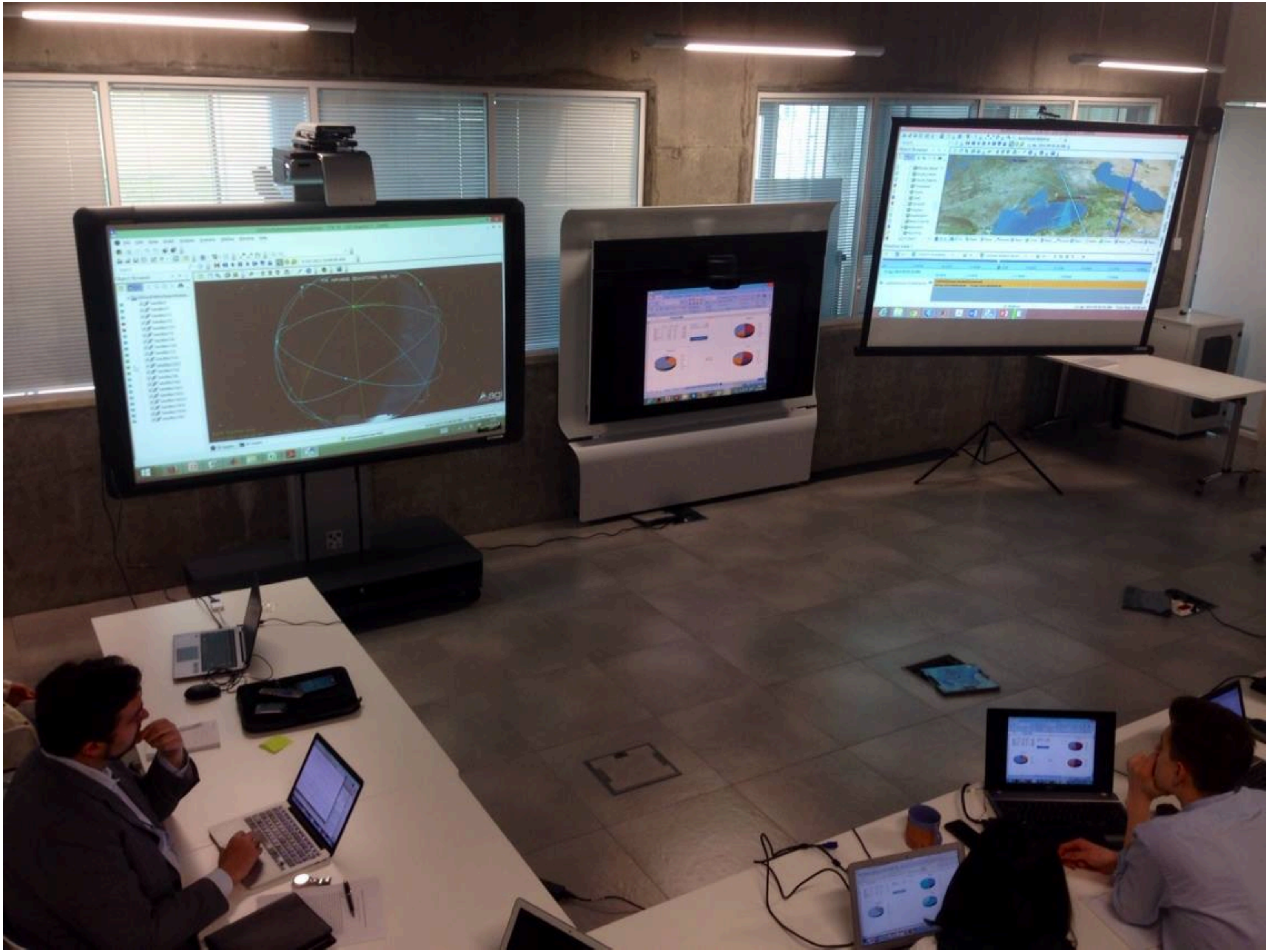
WHAT DID WORK

- Split infrastructure in separate rooms.
- Higher degree of reconfigurability compared to other CDFs (smart design tables)
- Ability to split room in two enhances flexibility of facility.
- Full control of infrastructure through impact (integrated control) simplified management using standard IT equipment that is easily replaceable if need be.

Lesson Learnt 1: Understand your needs by developing a low-cost interim CE facility and run a test study

- Interim facility as means to validate needs and clarify requirements with organization and constractors.
- Typical ‘subsystems’ to consider: People, Processes, Tools, IT Software, IT Hardware, Infrastructure
- Disciplinary knowledge may or may not be part of the facility.
- Need to accommodate multiple interface standards for same interface type
- Engage stakeholders in verification/validation but also in understanding functionality and range of applicability of CE infrastructure

Our Interim Concurrent Engineering "Facility" (2014)



Lesson Learnt 2: Design infrastructure functionality and elements according to your organization's needs

- No Size Fits All
- CE facilities may be implemented at different scales and purposes.
- In other words, a design facility needs to be designed, conducting performance-cost tradeoffs that are appropriate for the organization.
- Shall we invest more in tools? Shall we invest more in people? Shall we invest more in infrastructure?
- Many of these questions are answered by experience.

Lesson Learnt 3: Develop the infrastructure using separated spaces to accommodate different functional needs.

- We found space separation to be very effective in implementing concurrency by *lateral coordination*.

- Enabling open and clear communications among team members while running structured design processes in parallel.

- A CE infrastructure needs to enable:
  - *Individual concentration*
  - *Creative brainstorming*
  - *Study observing*
  - *Breakout design streams*

Lesson Learnt 4: Reconfigurability, upgradeability, and maintanability are key; explicitly account for them in the design.

Upgradeability. Make sure your CE facility is easily upgradeable and avoid solutions that lead to technology lock-ins or costly replacements

- Mobile workstations better than desktops.

Reconfigurability – to what degree is it required? (reconfigure every day? Every week? Every session?)

- This drives choice of furniture – design tables – which may be an important cost driver if maximum flexibility is chosen.

Maintainability – beware of cabling. We wanted to have a fully wireless facility but we could not. At the minimum, you need a power cable, and a video/data cable for high resolution video streams.

- Floor boxes are clumsy and tend to ‘cut’ your cables.
- Dedicated WiFi is a good idea if pursuing fully wireless solution

More on Maintainability. CE facility is a highly complex system for which many emergent behavior (unintended also) will appear during the course of the first weeks of operations.

- Maintain a structured knowledge base with issues encountered and solutions.
- Dedicated engineer to maintain the facility is needed.

PRACTICAL TIPS

Lighting. Very important to study lighting within environmental context (orientation of the building with respect to sunlight) and take appropriate measures to avoid unintended glares and shadows.

Cabling. CE facility may require significant amount of cables. Possible solution is raised floor. Account for successive upgrades and maintenance events.

Heat. Video walls generate significant heat! Need to design dedicated cooling system (active or passive) + coordinate with A/C of the facility.

WHAT COULD HAVE WORKED BETTER IN OUR PROJECT

Lesson Learnt 6: Clarify the scope of a CE facility to contractors before design and implementation, using a CE demo study

- CE facilities are not built everyday. Contractors may confuse it for ‘fancy class’ or ‘sophisticated cinema’

- Be very specific in defining use cases and requirements. Do not assume contractor understands purpose of a CE facility.

Lesson Learnt 7: Engage stakeholders in verification/ validation but also in understanding functionality and range of applicability of a CE infrastructure

- Purpose of a CE facility is rarely clear to experts who have never participated in a concurrent design study.

- Early involvement of stakeholders and their participation to a demo study is highly recommended to bring management onboard your project.

- After demo study, our critics became our best sponsors.

- If we were to start this project from scratch, we would involve stakeholders more intensively from day 0 of the design of the infrastructure.

Lesson Learnt 8: Accommodate multiple interface standards for the same interface type.

- We strived to achieve full interoperability on any heterogeneous set of Windows and Mac computers, tablets, and even smartphones.
- We partially achieved our goal. We discovered several limitations imposed by specificities of certain standards.
- We found issues in relaying on fully wireless facility in streaming HD video for 3D CAD modeling purposes.
- After extensive tests, we determined there was no way to escape from wires for certain types of interfaces.

Lesson Learnt 9: We wanted to have a fully wireless facility; we discovered this to be no easy task. This goal seems not to be easily achievable with current commercial wireless technology.

- Wires are still needed for 4K high resolution video streaming, high-speed Internet connections, and teleconference infrastructure.
- Part of these limitations were driven by budget constraints.
- We eventually set back on a need of three wired connections per design seat.
- Implemented a color-coded wiring system to allow quick reconfigurability of design seats in the facility.

IN CONCLUSION…

CHALLENGES

- Challenges in our design depended on both human factors and infrastructure related issues.
  - Initial skepticism on the purpose and usefulness of developing a concurrent engineering design facility.
  - We appreciated that the value proposition could only be effectively communicated by experience → involve your stakeholders in a demonstration study and in the design process of the infrastructure.
- Cables, cables, cables.
- Heating issues not negligible when running a facility with tens of wall screens.
- Interconnection between breakout rooms is key. Make sure contractors understand scope and purpose of this need.

THREATS

Facility purpose and capabilities may be misinterpreted by sponsor or management

- It is not a facility only to enable distributed studies
- Facility does not usually provide disciplinary knowledge. This has to come from sponsor or from user.

“People” factor. Experts need to be trained to the use of CE. Most of value of CE is made evident after first use; may face skepticism at first glance.

OPPORTUNITIES

- From a breakout room you can both follow the data flow and the process without interfering. May be useful also for academic facilities pursuing methodological / process improvement studies.

Flexibility in exploitation of the facility

- Mainly due to our nature as academic institution.

End to end MBSE enabler. From paper to the machine shop floor.

Future work: Connect CEDL to manufacturing floor to enable end to end concurrent engineering.