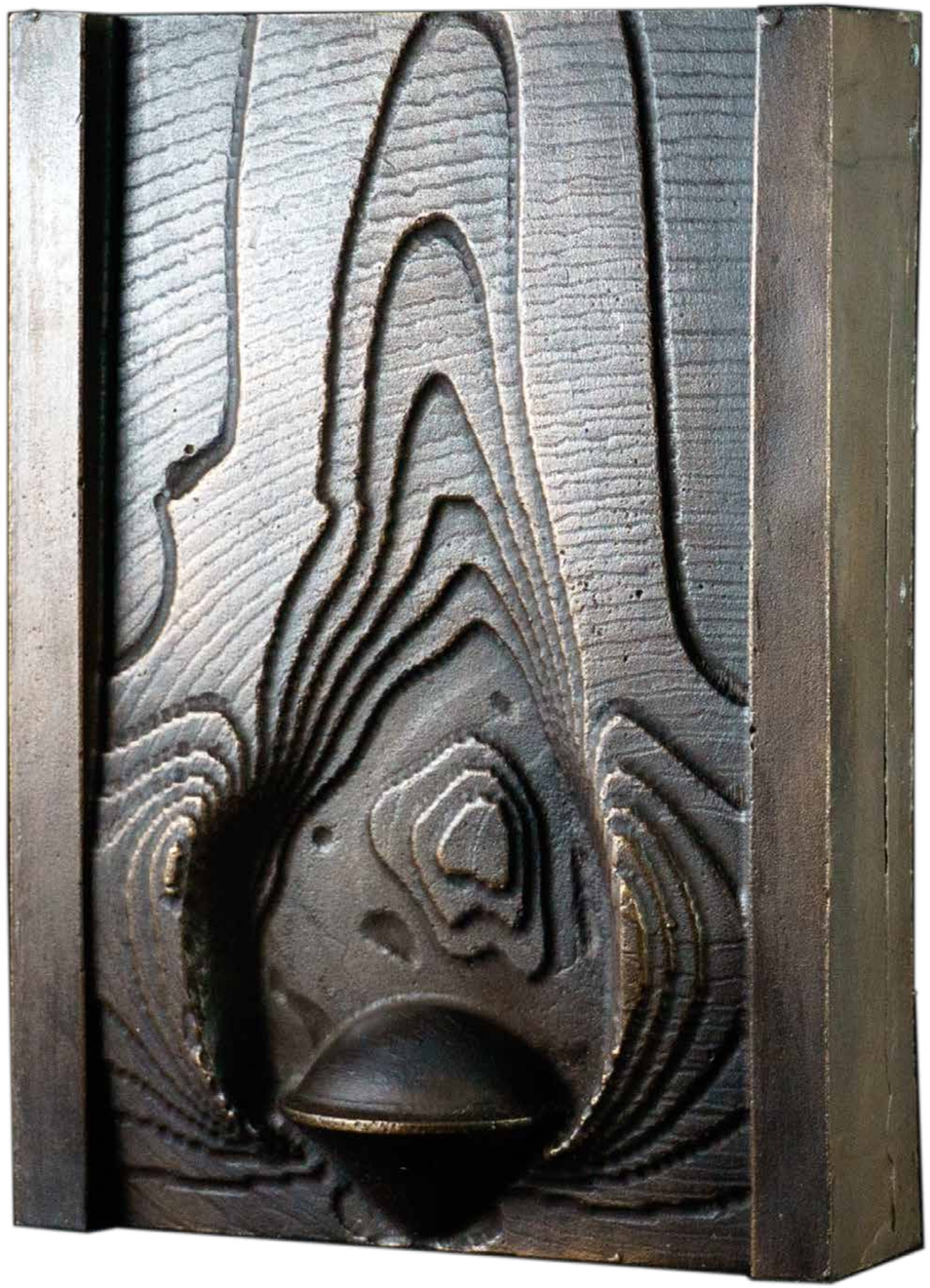
Design Space for Space Design:
Cybernetics, Human-Centered Design, and NASA



Future In-Space Operations (FISO)

colloquium presentation by

Dr. **Tibor Balint**

RCA IDE Research

FISO Telecon 07-06-2016

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Challenges

- NASA operates in an engineering / technology driven paradigm
- We keep repeating the same talking points year after year...
- ...expecting and hoping for different outcomes
- Increasingly specializing our language, which limits the introduction of new ideas and novel options

Let’s start with innovation barriers

(on the scale of projects & programs)

NASA’s technology base is largely depleted, and future success will depend on advanced technology developments.

[NRC, 2012] [Balint, 2013]

Innovation barriers for space technology

- Risk averse culture
- Low priority on innovation + short term focus
- Instability
- Lack of opportunities
- Process overload
- Communication challenges
- Organizational inertia

[NASA, 2013] [Balint, 2013]

Some examples to overcome innovation barriers

- Creative ideation (e.g., bootlegging)
- Innovation laboratories & Creative spaces (e.g., TeamX)
- Innovation funding (e.g., STMD-CIF; IRAD)
- Skunkworks

- Combination of the above

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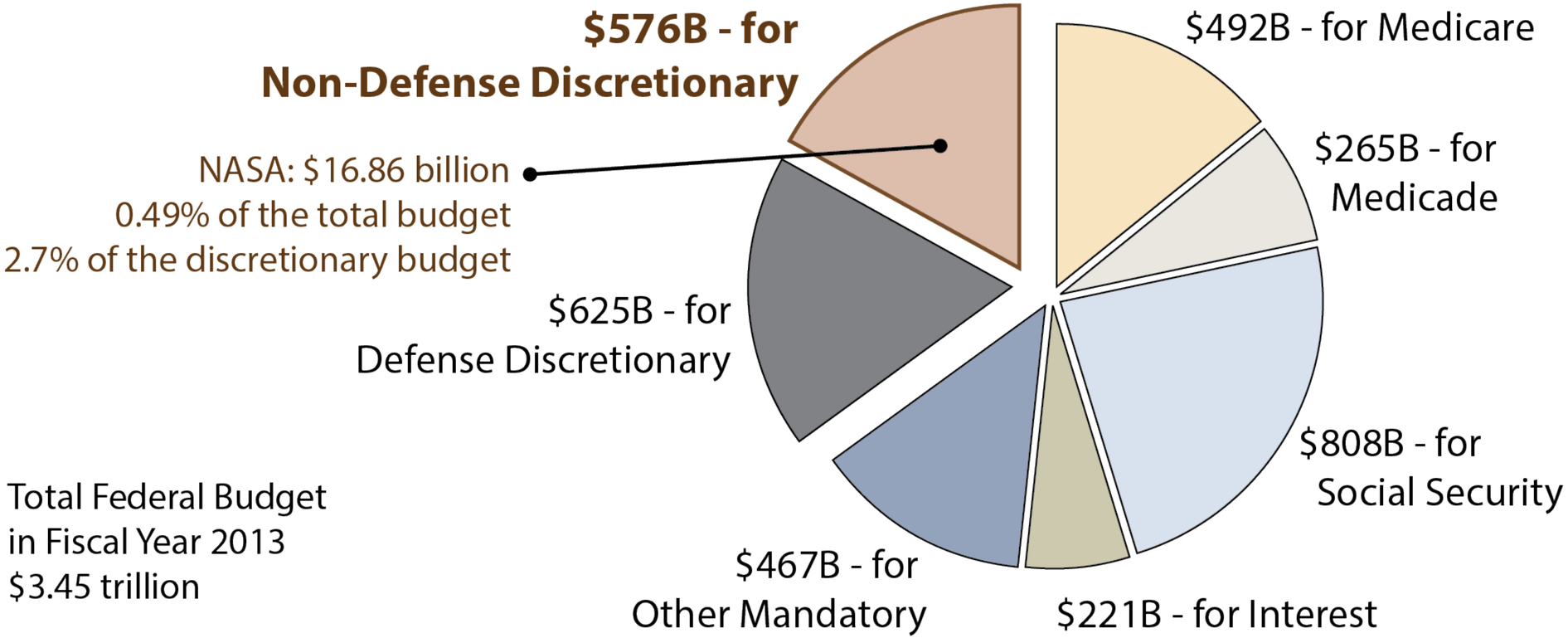
[Dodgson & Gann, 2010] [Balint, 2013]

Wicked problems for tech development

(looking at it on a broader scale)

FY13 federal budget breakdown

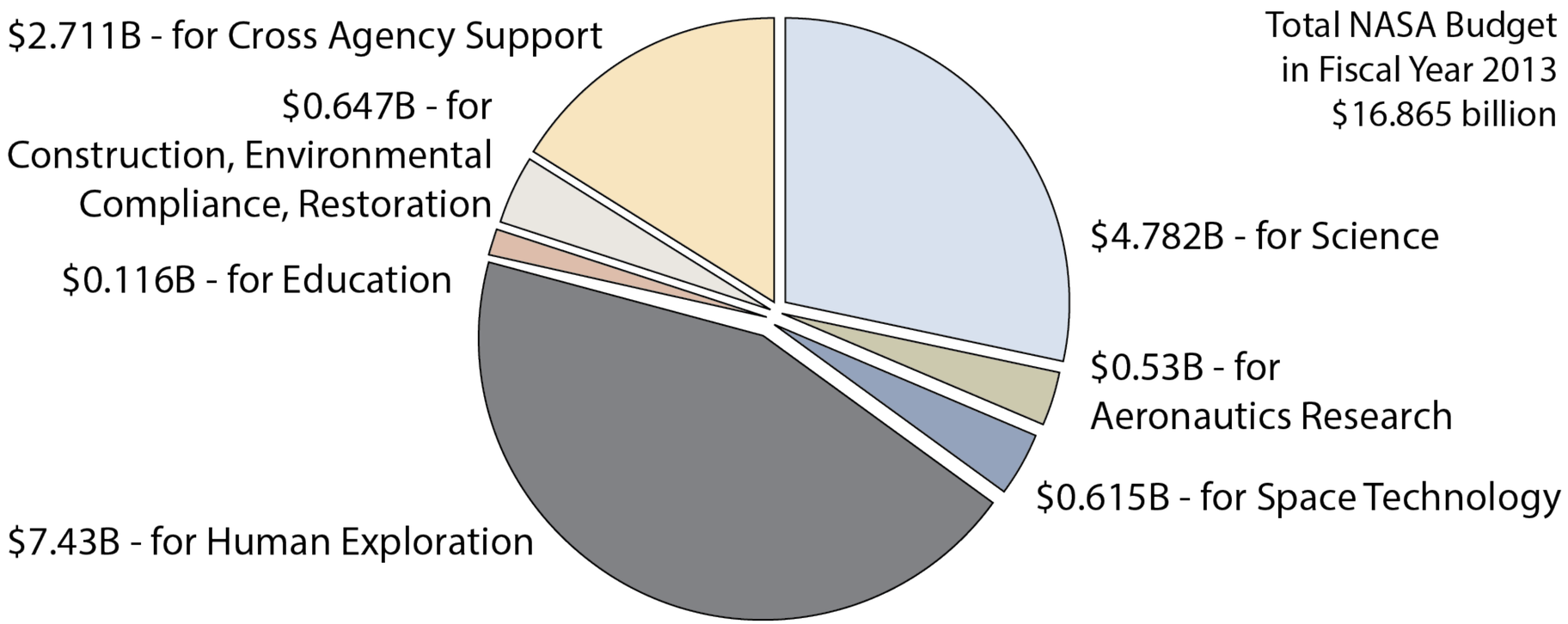
0.49% (2013)
4.4% (1966)



[HoR, 2014][Balint & Stevens, 2014]

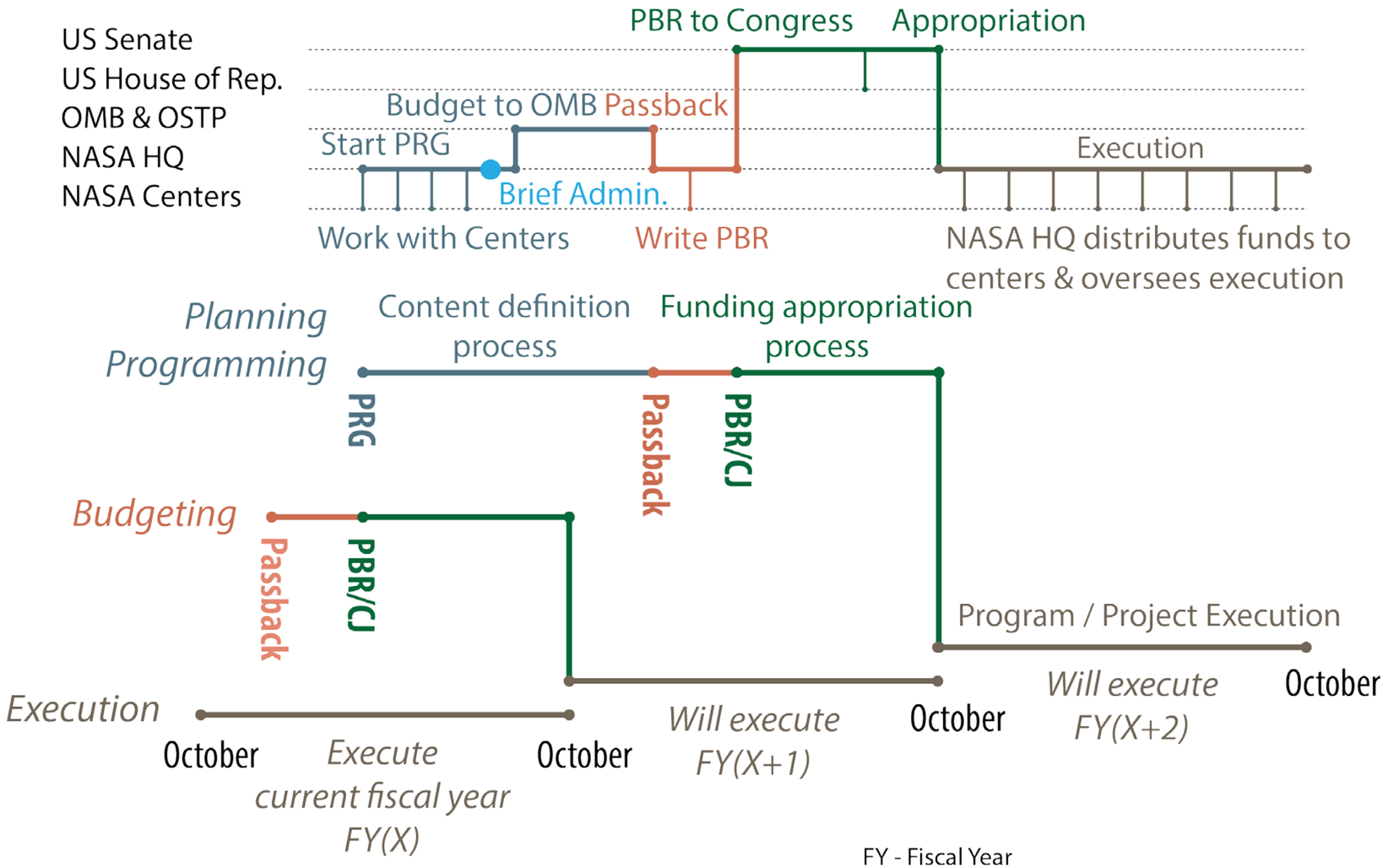
FY13 NASA budget breakdown

$16.8B (FY13)
$19.3B (FY16)



[NASA, 2014][Balint & Stevens, 2014]

NASA's PPBE process



NASA HQ - NASA Headquarters
OMB - Office of Management & Budget (Executive Branch)
OSTP - Office of Science & Technology Policy (Executive Branch)
US Congress - House of Representatives & Senate (Legistlative Branch)

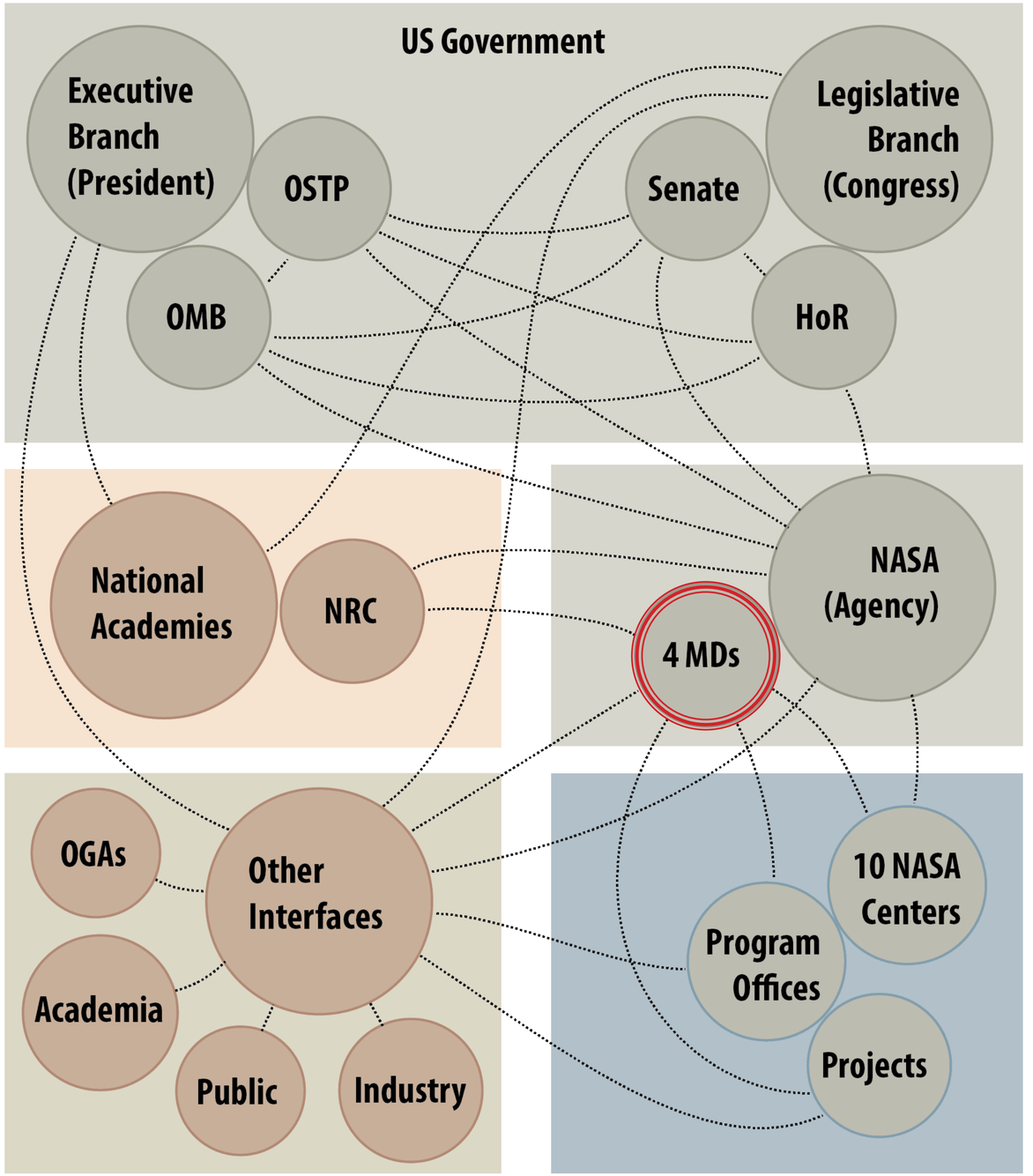
FY - Fiscal Year
PPBE - Planning, Programming, Budgeting, & Execution
PBR - President's Budget Request
CJ - Congressional Justification
PRG - Program and Resrouce Guidance

[Balint & Stevens, 2014]

NASA's wicked problem

OSTP.....Office of Science and Technology Policy
OMB.....Office of Management and Budget
HoR.....House of Representatives
OGAs.....Other Government Agencies
NRC.....National Research Council
MDs.....Mission Directorates at NASA
[L1]-[L3]...NASA Organizational levels 1 to 3
SMEs.....Subject Matter Experts

NASA operates through a spatially & temporally coupled, cyclical wicked problem.



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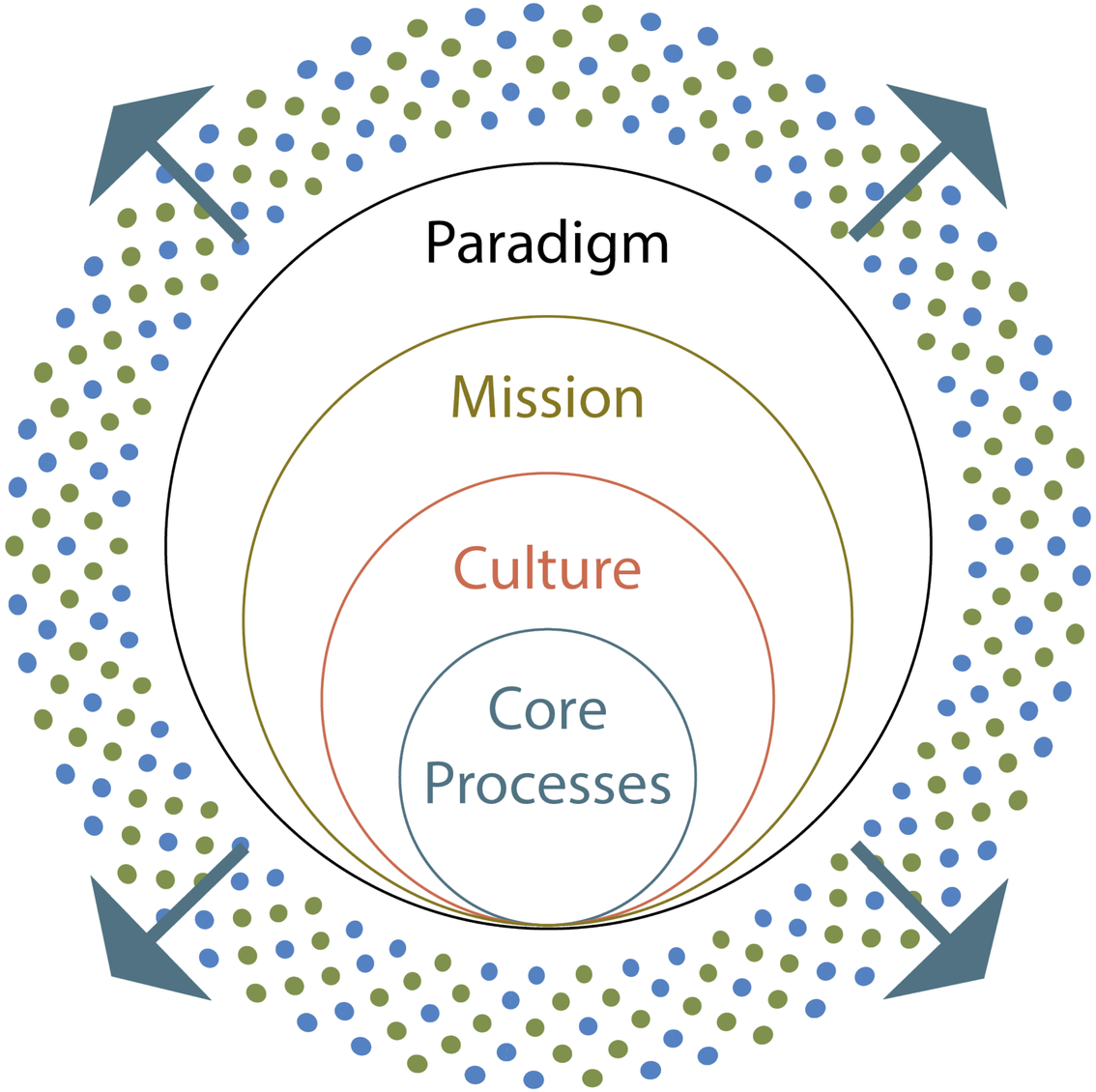
[Balint & Stevens, 2014]

Changing / broadening the paradigm

(potential roles of cybernetics & design)

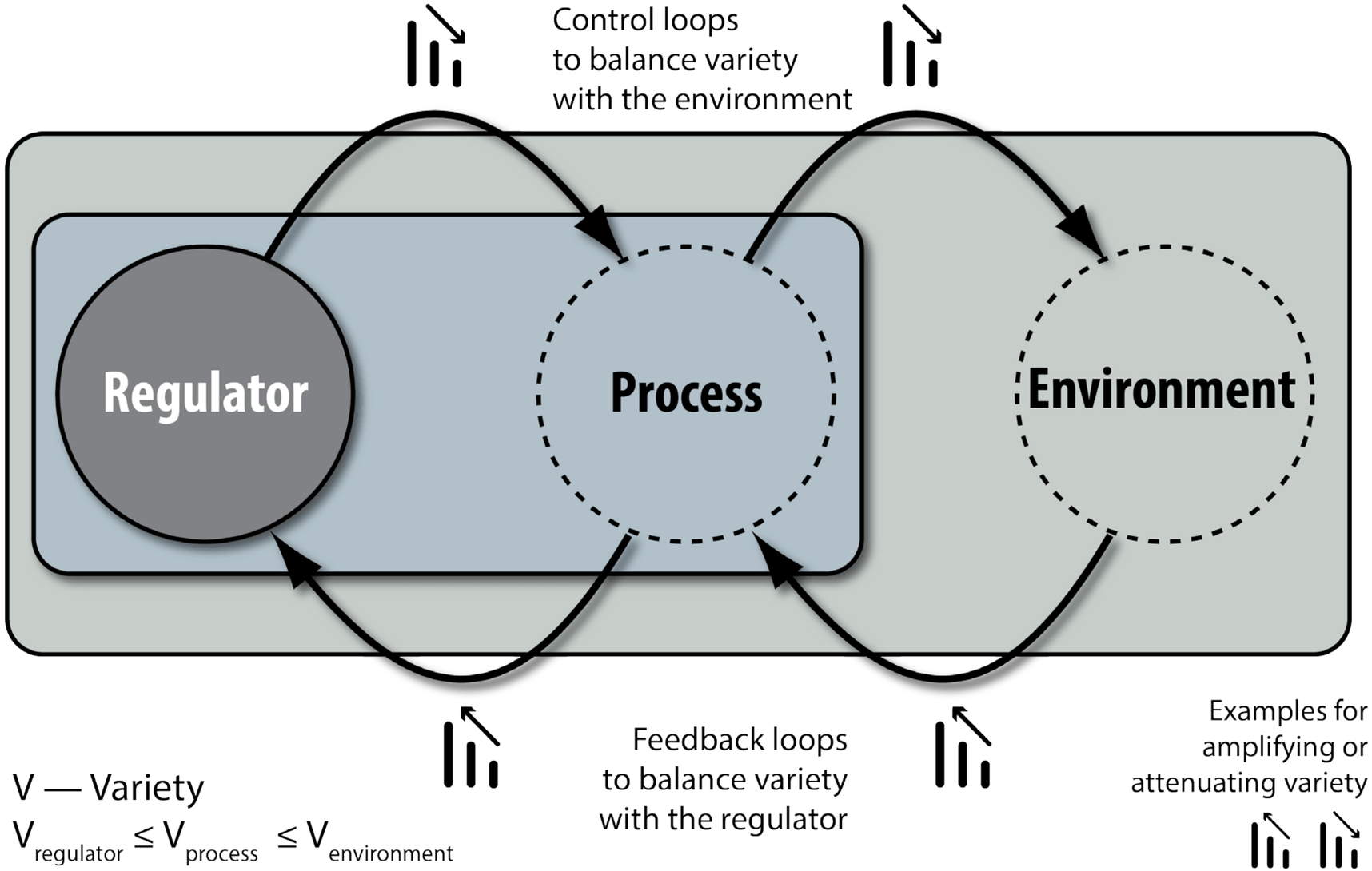
To introduce new ideas,
to change the discourse,
we need new perspectives
& broaden the paradigm



Levy's Second Order Change

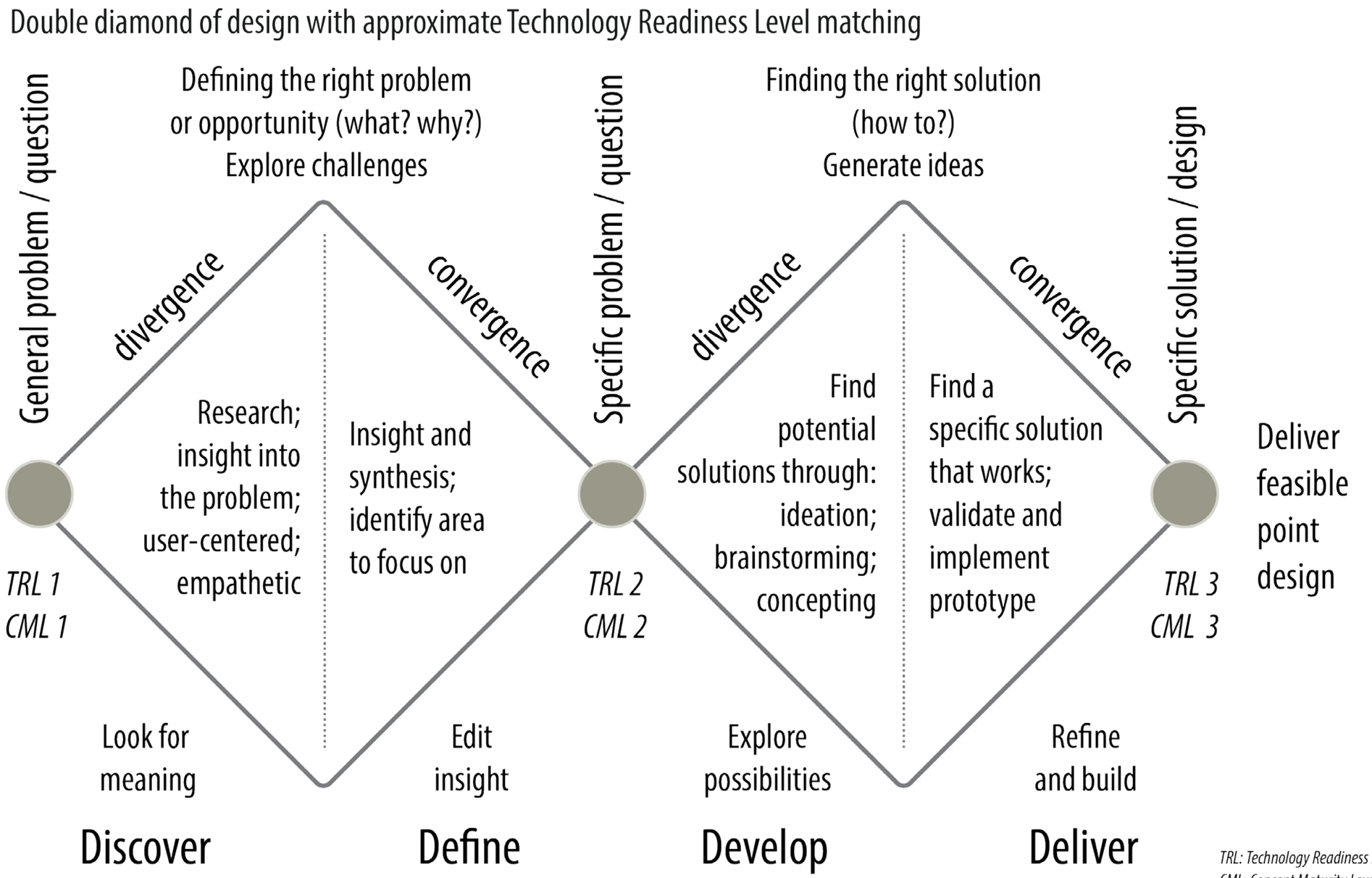
[Levy, 1986]

Cybernetics provides a perspective with focus on circular connections



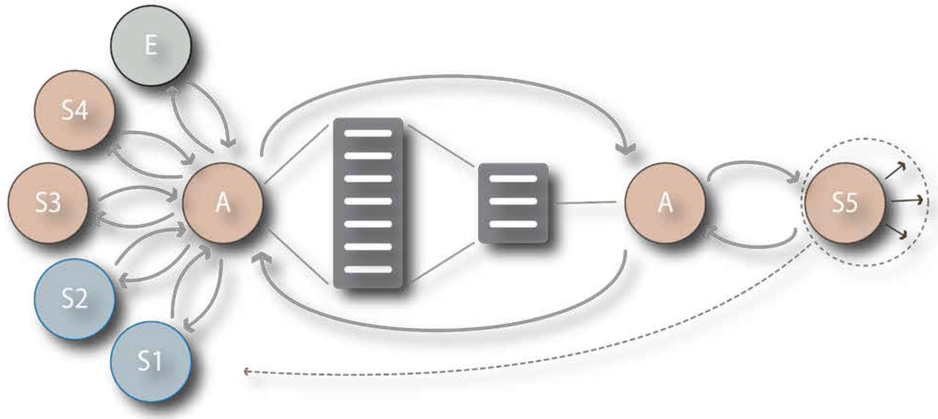
interpreted from [Wiener, 1948]

Design provides the means, goals, language and dialogs towards change



TRL: Technology Readiness Level
CML: Concept Maturity Level

Fracture Point 1:
Changing organizational processes through management cybernetics & design dialogs

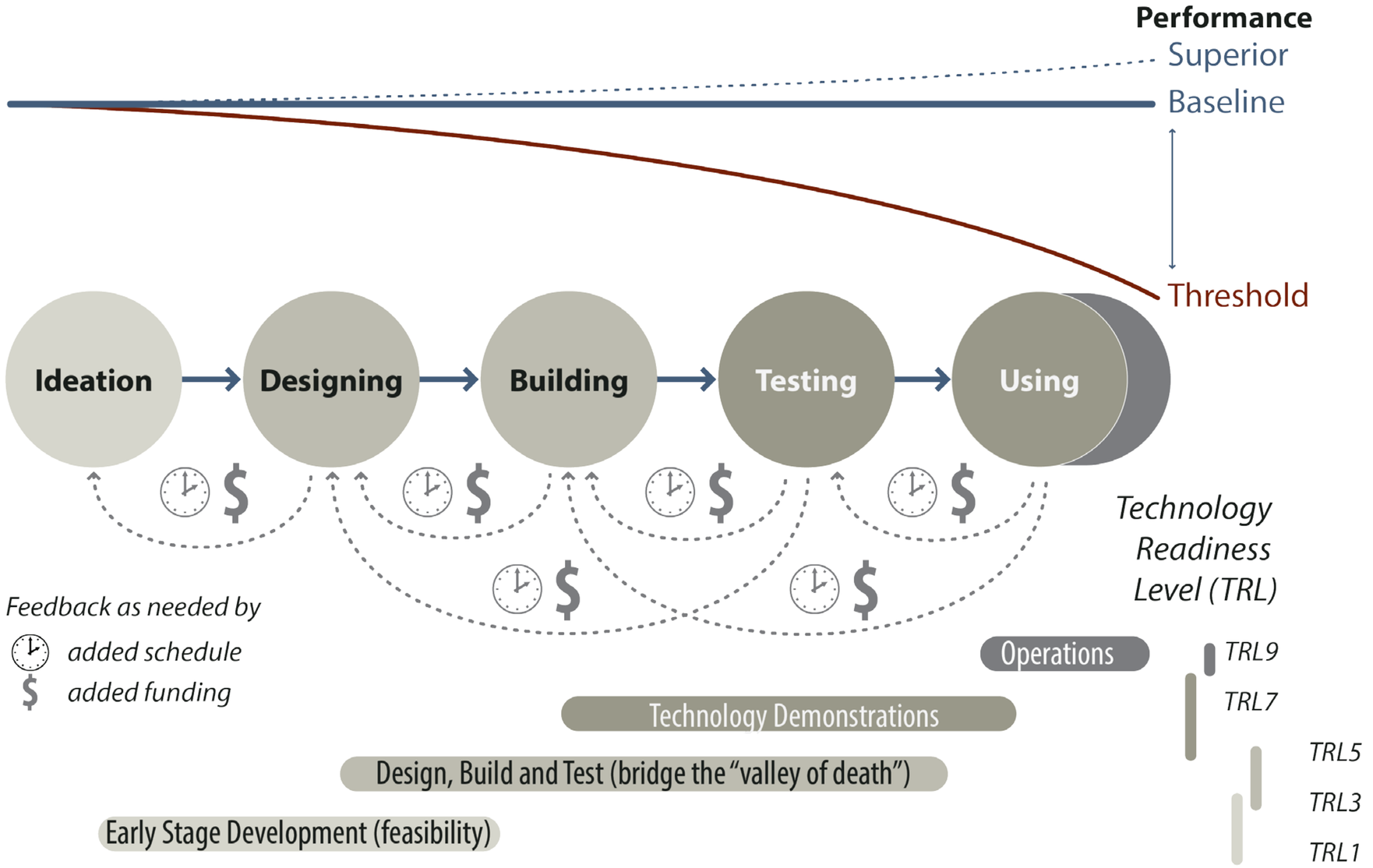


Project Assessment Framework Through Design (PAFTD)

[Balint et al., 2015]

- Typical project reporting focuses on linear project execution progresses, related to feasibility & viability

Feedback loops are inputs for regulatory control decisions



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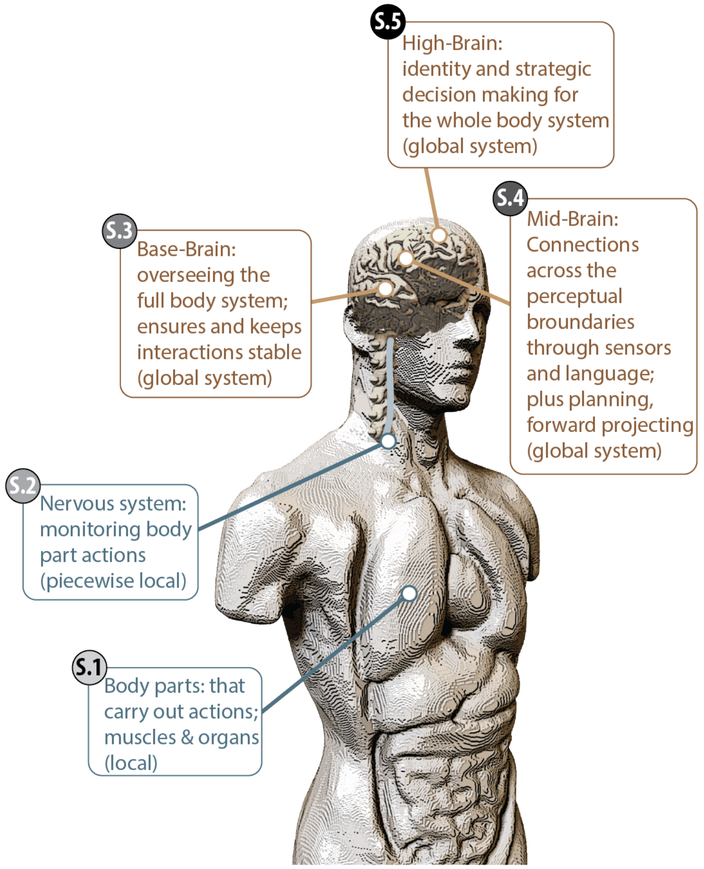
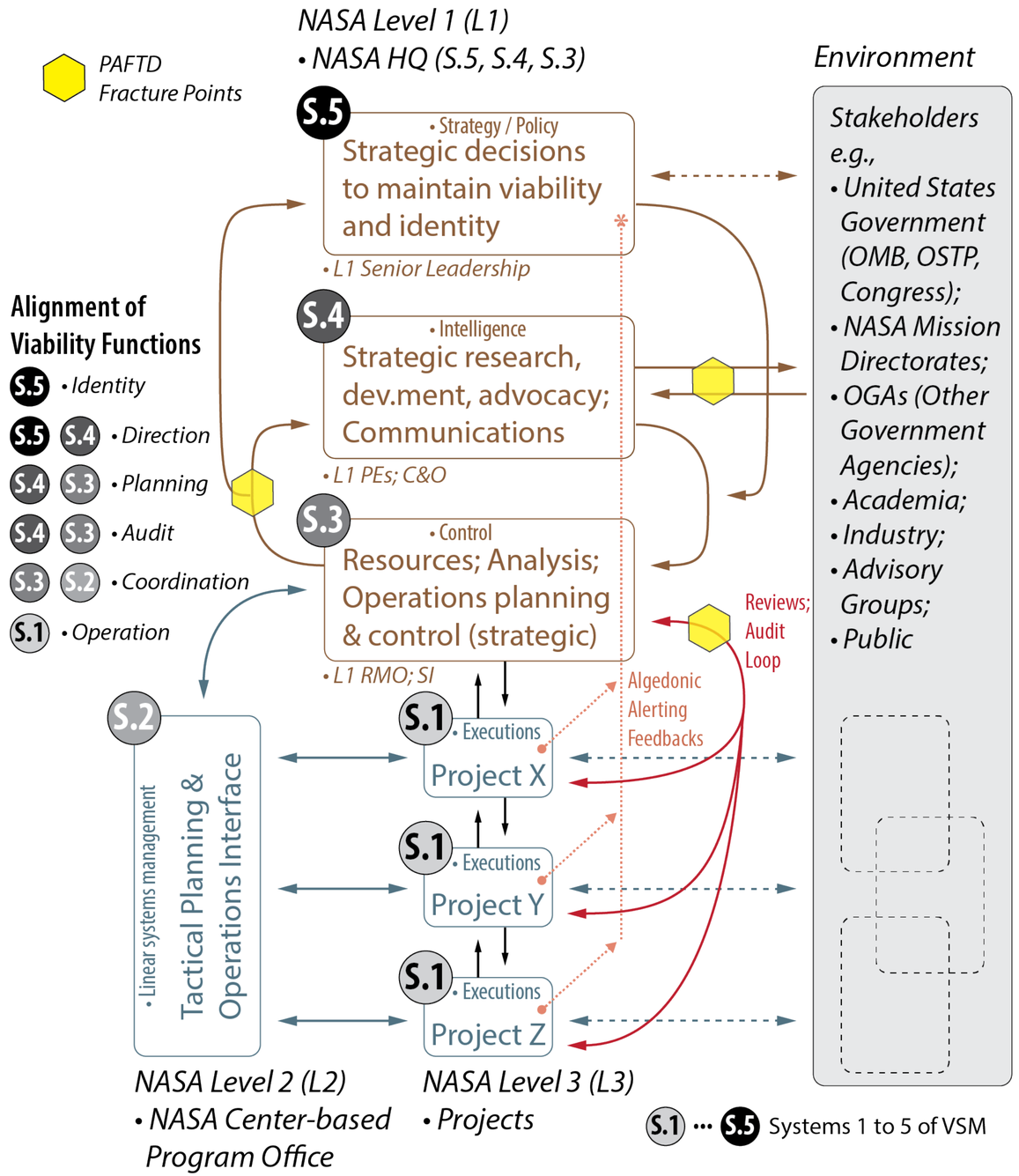
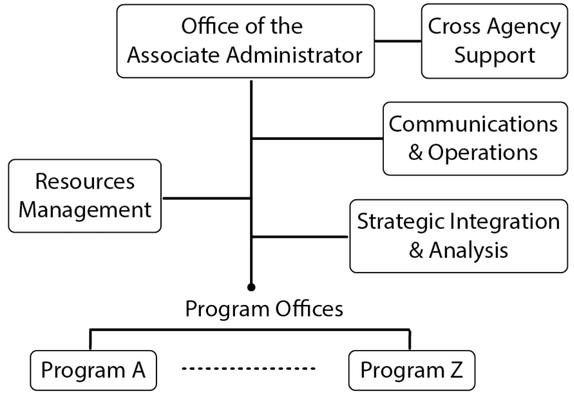
- Managing complex technology portfolios requires strategic perspectives and insights

- For this,
  we have developed PAFTD as a unique tool
  to systematically assess dynamic project performance
  from a strategic level, through design dialogs







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[Balint et al., 2015]

1. Design Dialogs

Conduct interviews

2. Divergence

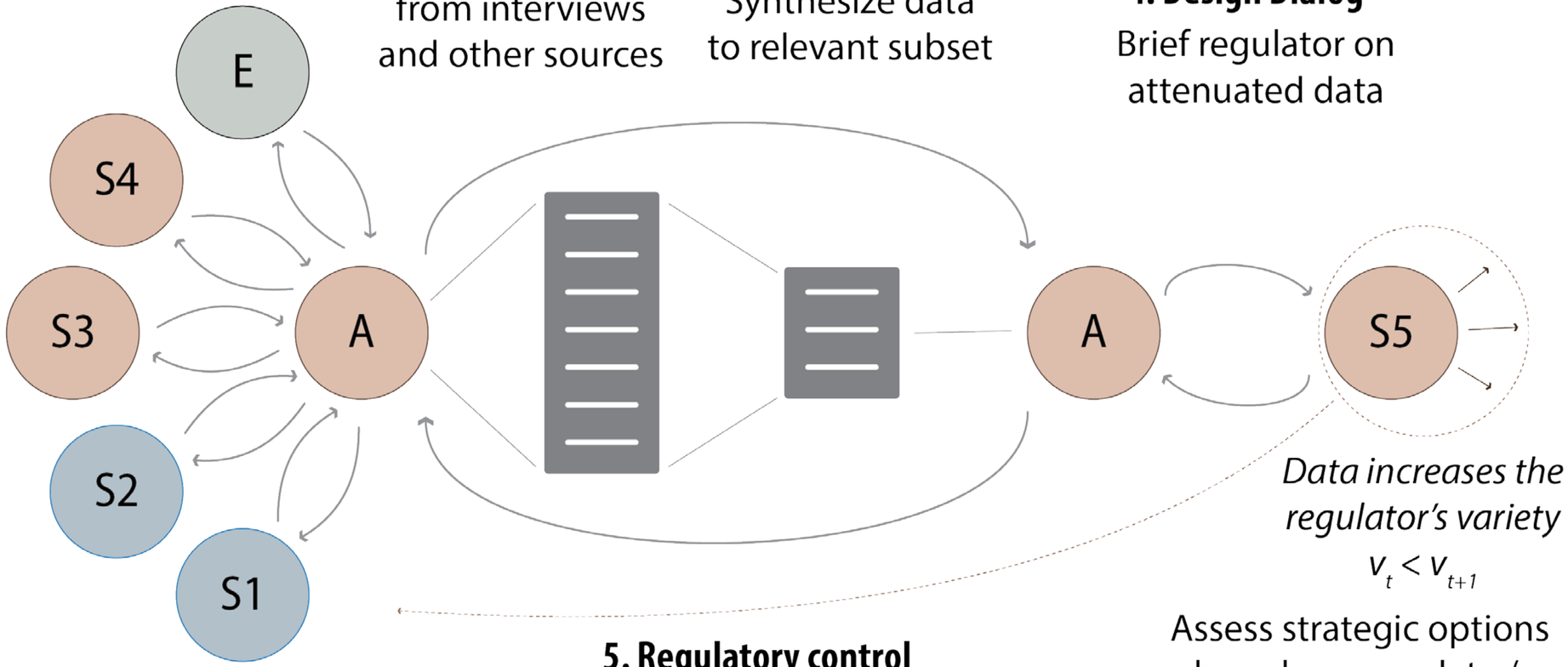
Analyze data from interviews and other sources

3. Convergence

Synthesize data to relevant subset

4. Design Dialog

Brief regulator on attenuated data



Data increases the regulator's variety

$v_t < v_{t+1}$

Assess strategic options based on new data / broadened S5 variety

5. Regulatory control

Follow on phase: Communicate strategic guidance to the project(s)

Legend:

S1 to S2 - Systems of a VSM organization (linear)
S3 to S5 - Systems of a VSM organization (strategic)

E - Environment / external stakeholders
A - Strategic level PAFTD analyst

v_t *- Variety before the briefing*
v_{t+1} *- Variety after the briefing*

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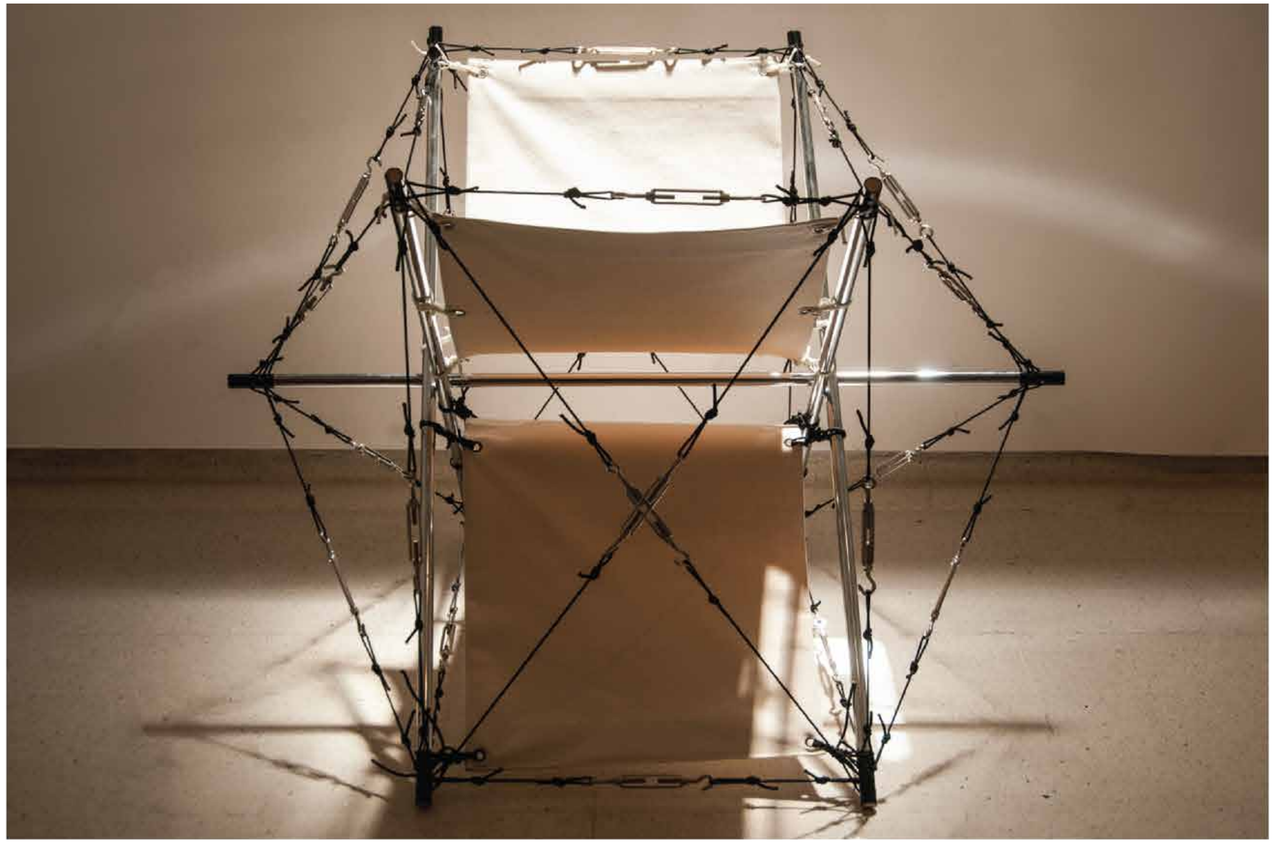
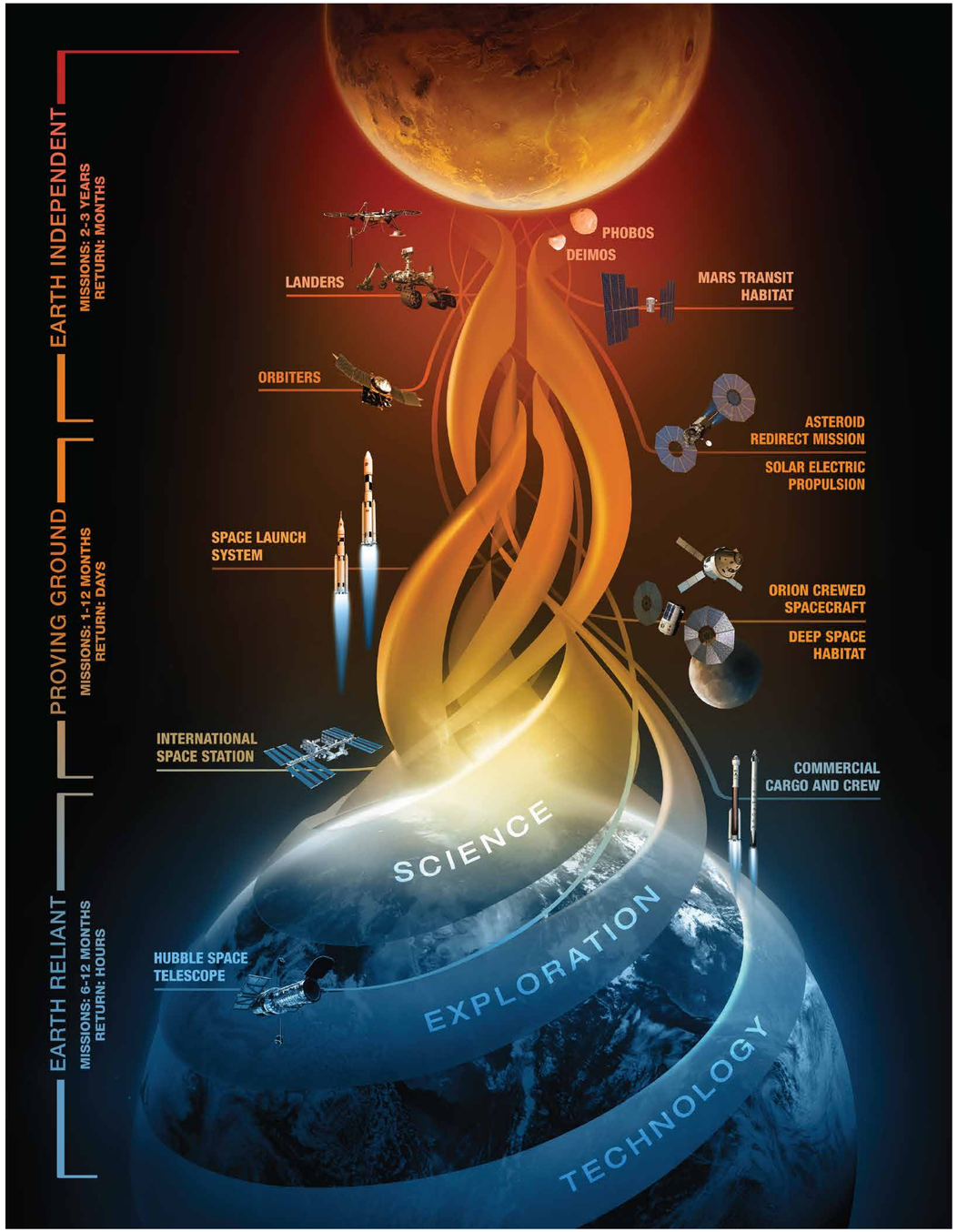
[Balint et al., 2015]

- To date, we have applied PAFTD to three high-TRL and one mid-TRL projects at NASA STMD
- Once briefed on the synthesized findings, senior leadership gained broader and more informed insights to strategic level project health
- The combination of strategic insights from PAFTD, and project level reporting on feasibility and viability allowed leadership to make strategic decisions and take corrective actions to benefit both the project and the overall portfolio
- Using cybernetics & the Viable System Model, with design dialogs allowed us to gain new perspectives on the organization and its operations

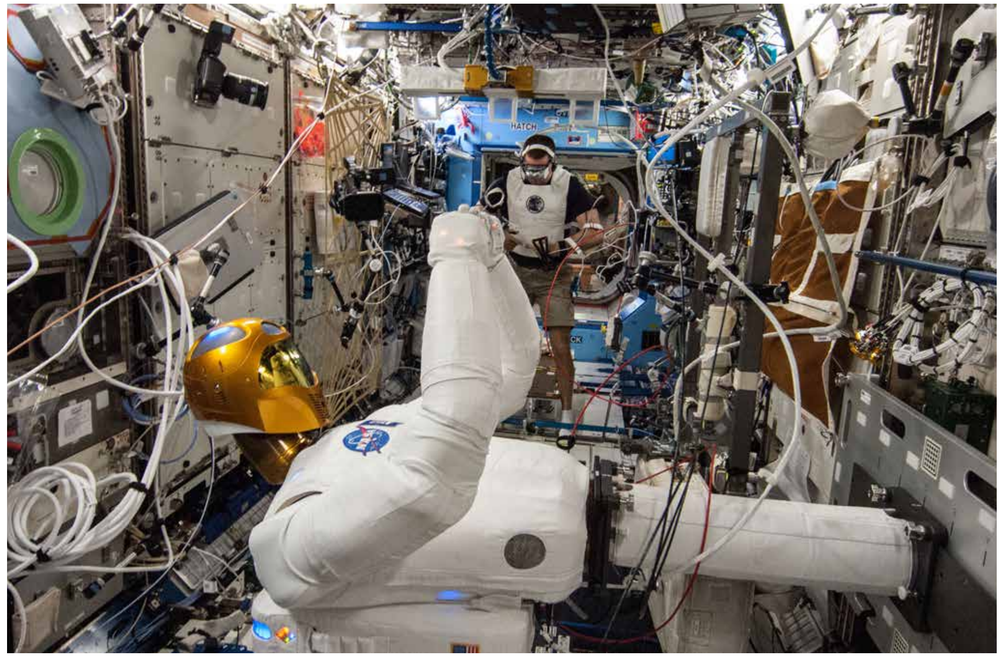
Fracture Point 2:
Changing space habitats through human centered design and cybernetics



[Balint & Hall, 2015a] [Balint & Hall, 2015b]


EARTH INDEPENDENT
MISSIONS: 2-3 YEARS
RETURN: MONTHS
PROVING GROUND
MISSIONS: 1-12 MONTHS
RETURN: DAYS
EARTH RELIANT
MISSIONS: 6-12 MONTHS
RETURN: HOURS
PHOBOS
DEIMOS
LANDERS
MARS TRANSIT HABITAT
ORBITERS
ASTEROID REDIRECT MISSION
SOLAR ELECTRIC PROPULSION
SPACE LAUNCH SYSTEM
ORION CREWED SPACECRAFT
DEEP SPACE HABITAT
INTERNATIONAL SPACE STATION
COMMERCIAL CARGO AND CREW
SCIENCE
EXPLORATION
TECHNOLOGY
HUBBLE SPACE TELESCOPE

Some ISS Delight



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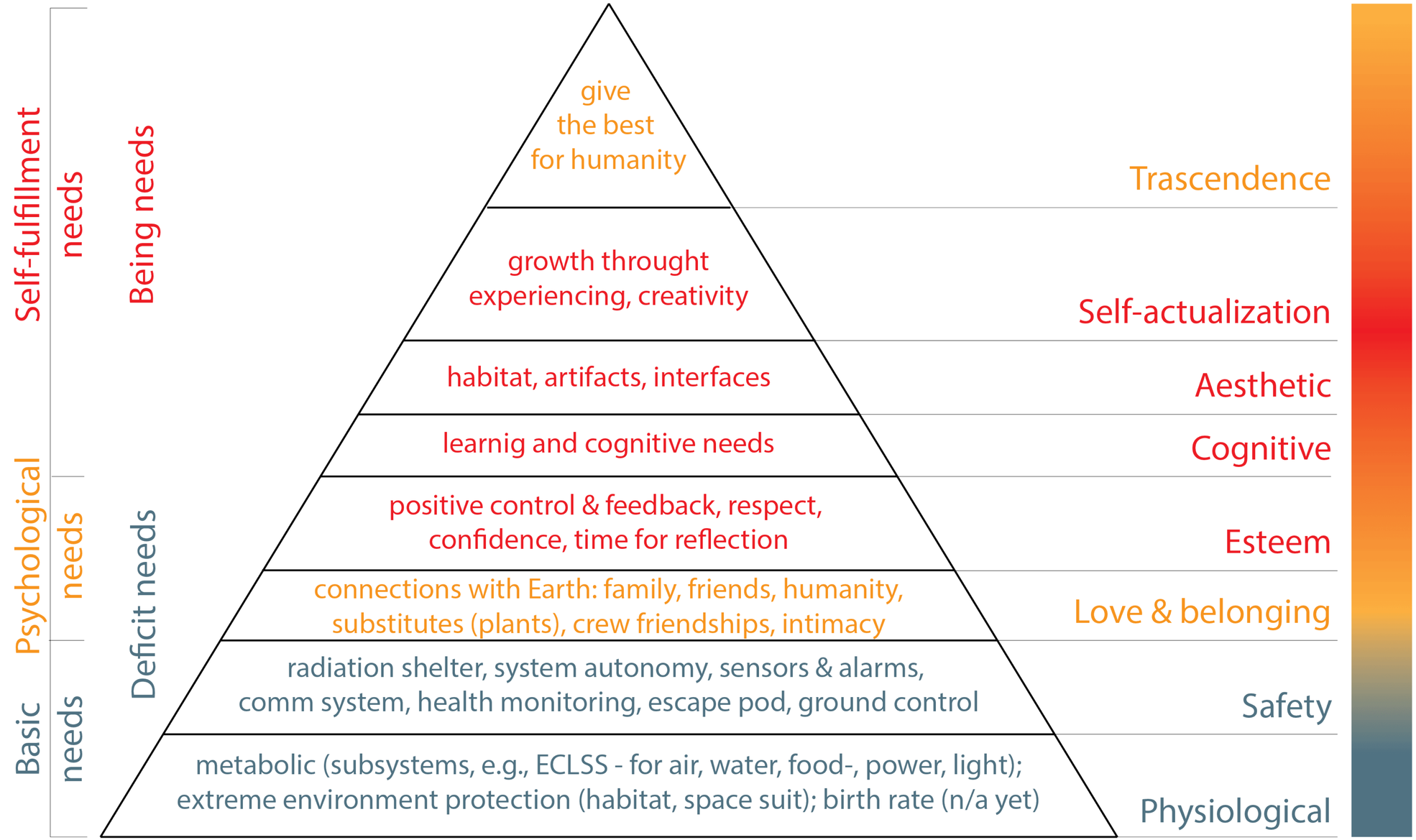
- *Identity (lip service)* S.5
- *Direction (short yes, long no)* S.5 S.4
- *Planning (short flight yes; long flight no)* S.4 S.3
- *Audit (Partial, short flight)* S.3 S.1
- *Coordination (ADDRESSED)* S.2 S.1
- *Operation (ADDRESSED)* S.1



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11 Emotional design & Empathy

12 Designed for space habitats (scale, immersion, interaction)

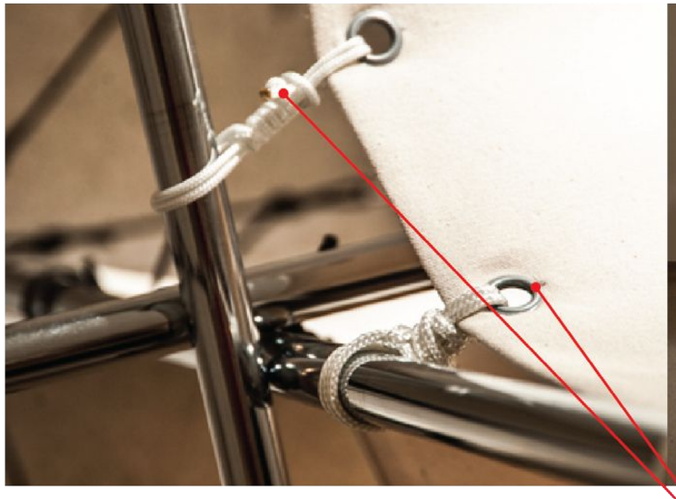
10 Interactions (peer-to-peer)

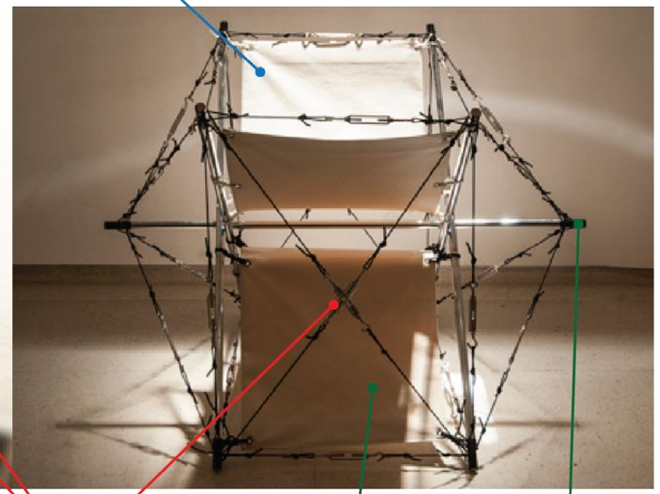
1 Zero-gravity - Extreme spaceflight environment

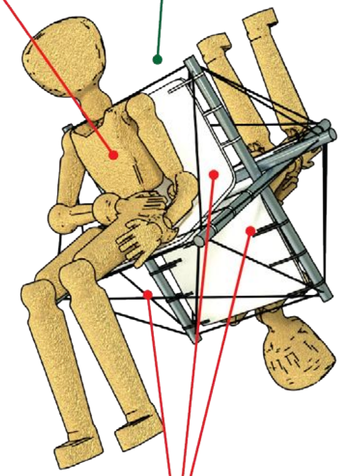
9 Human connections (emotional, physical)

2 Abstraction

8 Immersion / comfort







4 Signifiers

5 Safety

3 Affordances

13 Changing the meaning (assembled/disassembled use)

6 Mass, volume, dimensions

14 Multi-level storytelling (knowledge transfer; emotional)

7 Temporal & spatial dimensions

Design aspects
Artistic aspects
Architecture aspects
Engineering & Technology

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- We need to address higher level astronaut needs on long duration human spaceflight

- Engineering / technology / management driven solutions are not sufficient (e.g., surviving in solitary confinement)

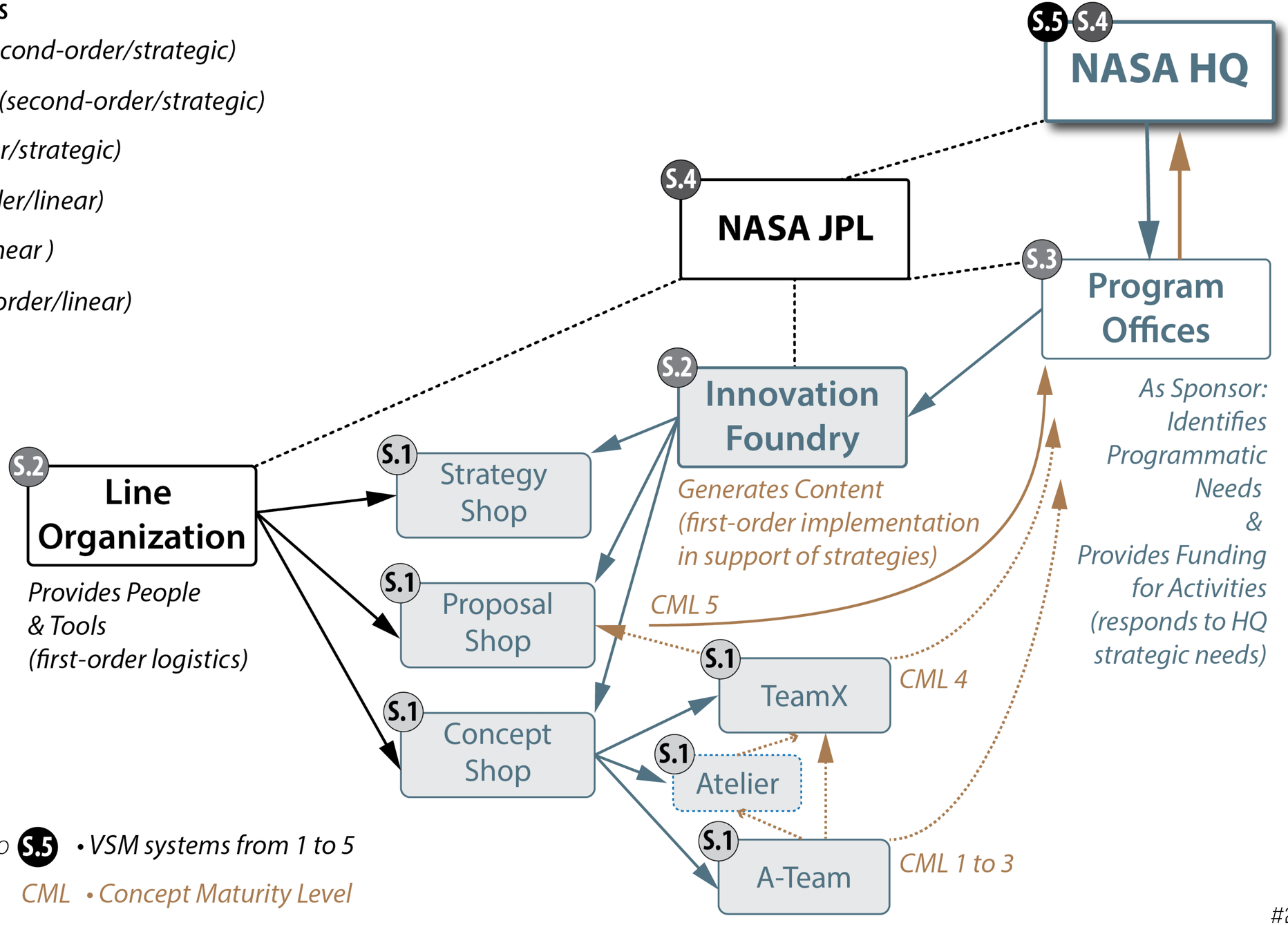
- For higher level human centered needs for the astronauts and their environments, we need to
  - establish appropriate guidelines
  - derive appropriate requirements
  - PLUS, have a forcing function from senior leadership to implement them

Fracture Point 3:
Changing design environments through cybernetics and design dialogs

[Balint & Freeman, 2016]

Alignment of VSM Viability Functions

- S.5 • *Identity/Strategy/Policy (second-order/strategic)*
- S.5 S.4 • *Direction/Intelligence (second-order/strategic)*
- S.4 S.3 • *Planning (second-order/strategic)*
- S.3 S.1 • *Audit/Control (first-order/linear)*
- S.2 • *Coordination (first-order/linear)*
- S.1 • *Operation/Execution (first-order/linear)*



S.1 *to* S.5 • *VSM systems from 1 to 5*

CML • Concept Maturity Level

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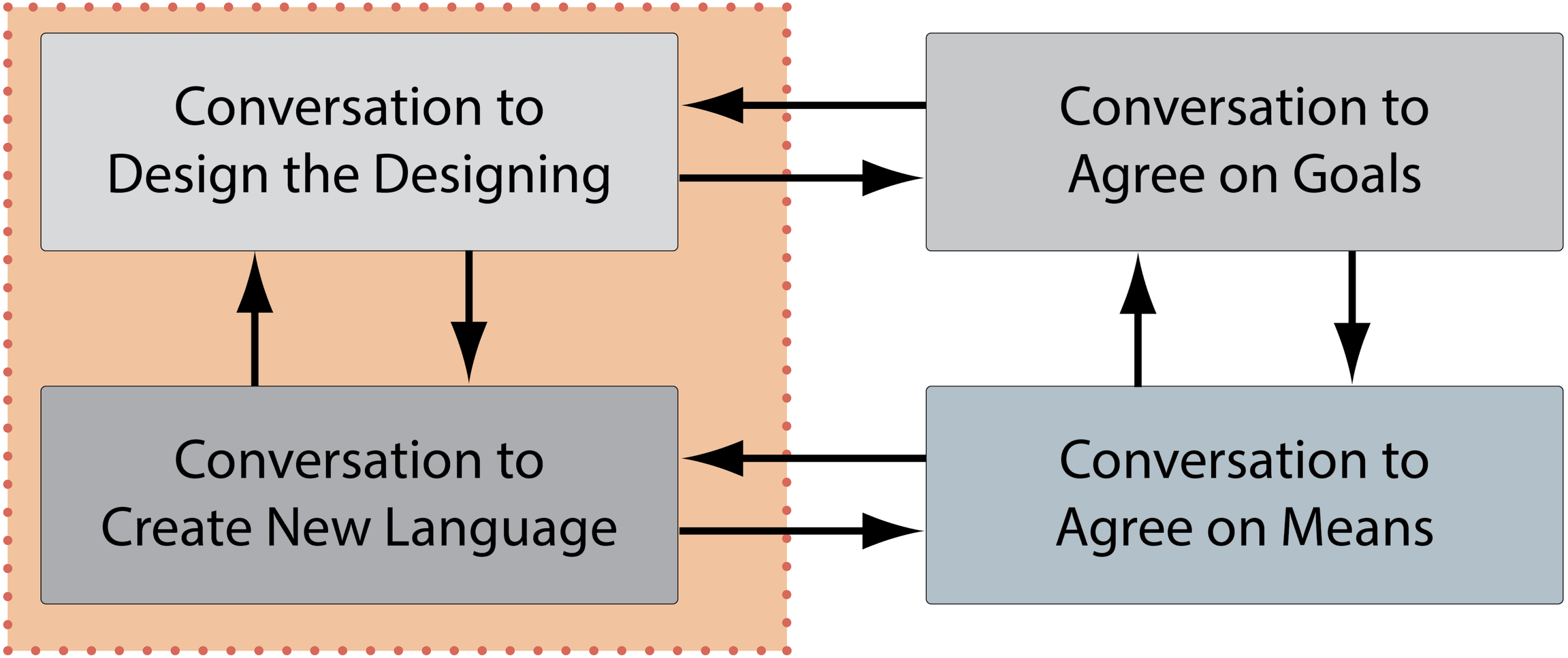
Pangaro's model of co-evolutionary design, organizations, or society

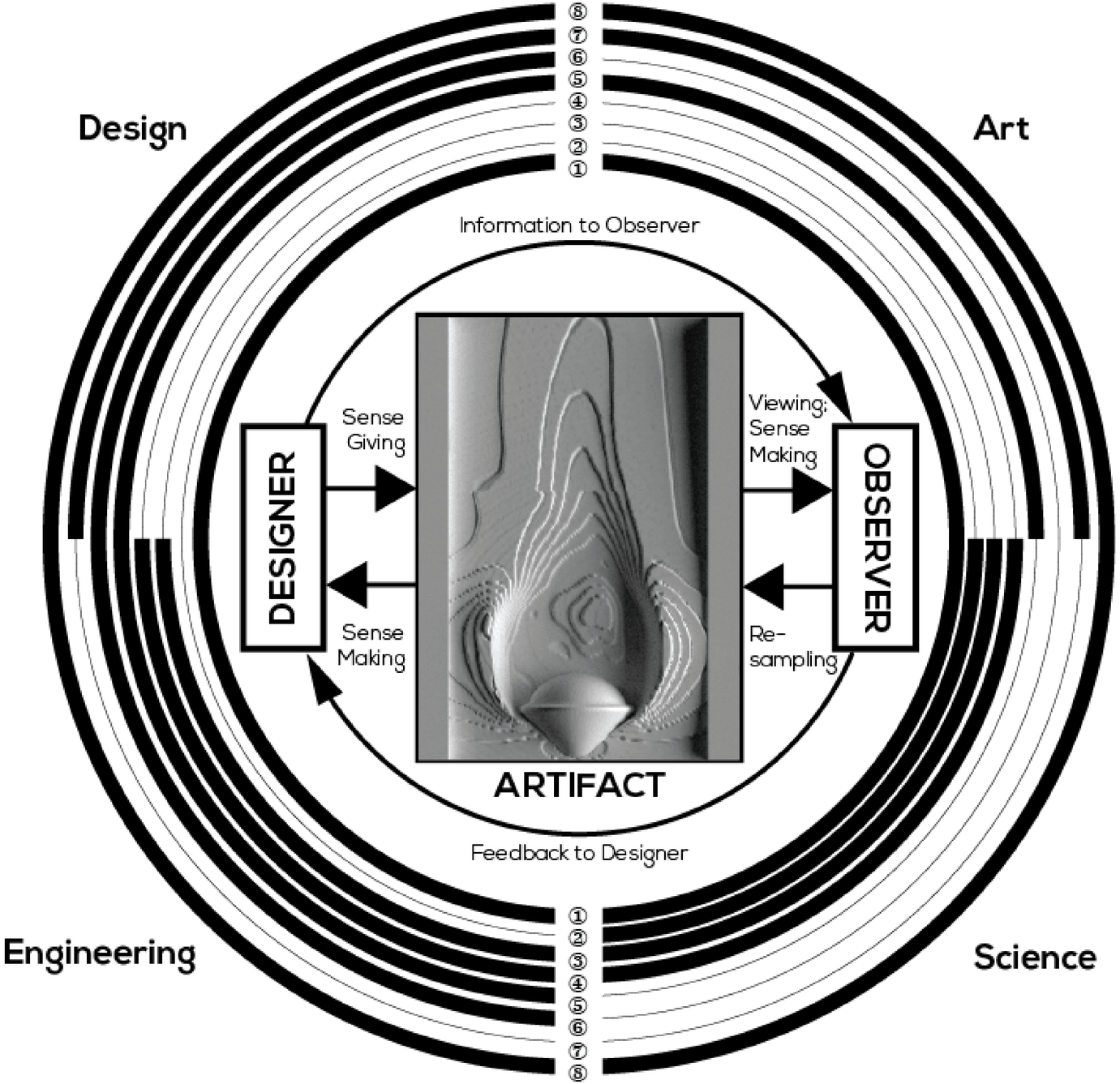


Pangaro et al.

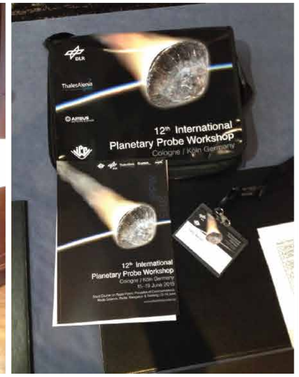
Boundary objects facilitate dialogs between disciplines

① Artistic Ideation
② Science of Fluid Flow
③ Computational Flow Modeling
④ Flow Visualization
⑤ Virtual Prototyping & Modeling
⑥ Making / CNC Machining
⑦ Making / Foundry Processes
⑧ Completed Artifact

Intersections & Cybernetic Dialogs Through a Boundary Object



Examples of Boundary Objects



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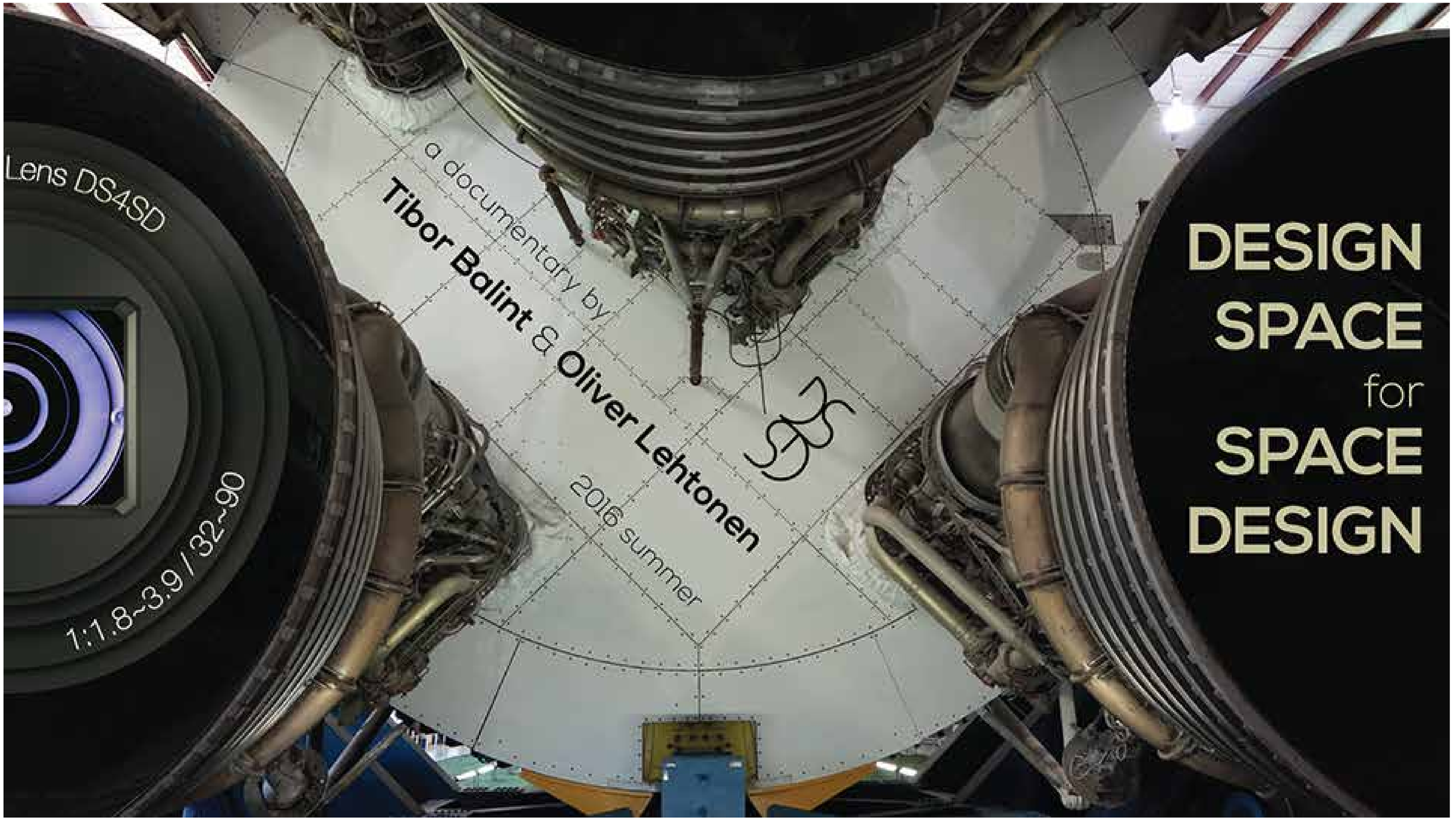
- Designers can play important roles in designing the design environments and improving communications between design teams; with stakeholders; with sponsors; and the public

- Boundary objects facilitate these dialogs in the intersections of disciplines
- These dialogs help to construct new languages between the participants
- New languages may introduce new options
- New options lead to preferable outcomes

Conclusions

Cybernetics -> Gives perspectives on connections
Design -> What to do about them?
Dialogs -> Finding a constructivist middle ground

- Works on every scale...
- ...From a single object to an organization...
- ...To create new languages, new options for NASA


Lens DS4SD
1:1.8~3.9/32~90
a documentary by
Tibor Balint & Oliver Lehtonen
2016 summer
DESIGN
SPACE
for
SPACE
DESIGN

Thank you

- Balint, T., 2016. "Making the Galileo Flow Field Artifacts," 13th International Planetary Probe Workshop, Laurel, MD, June 17
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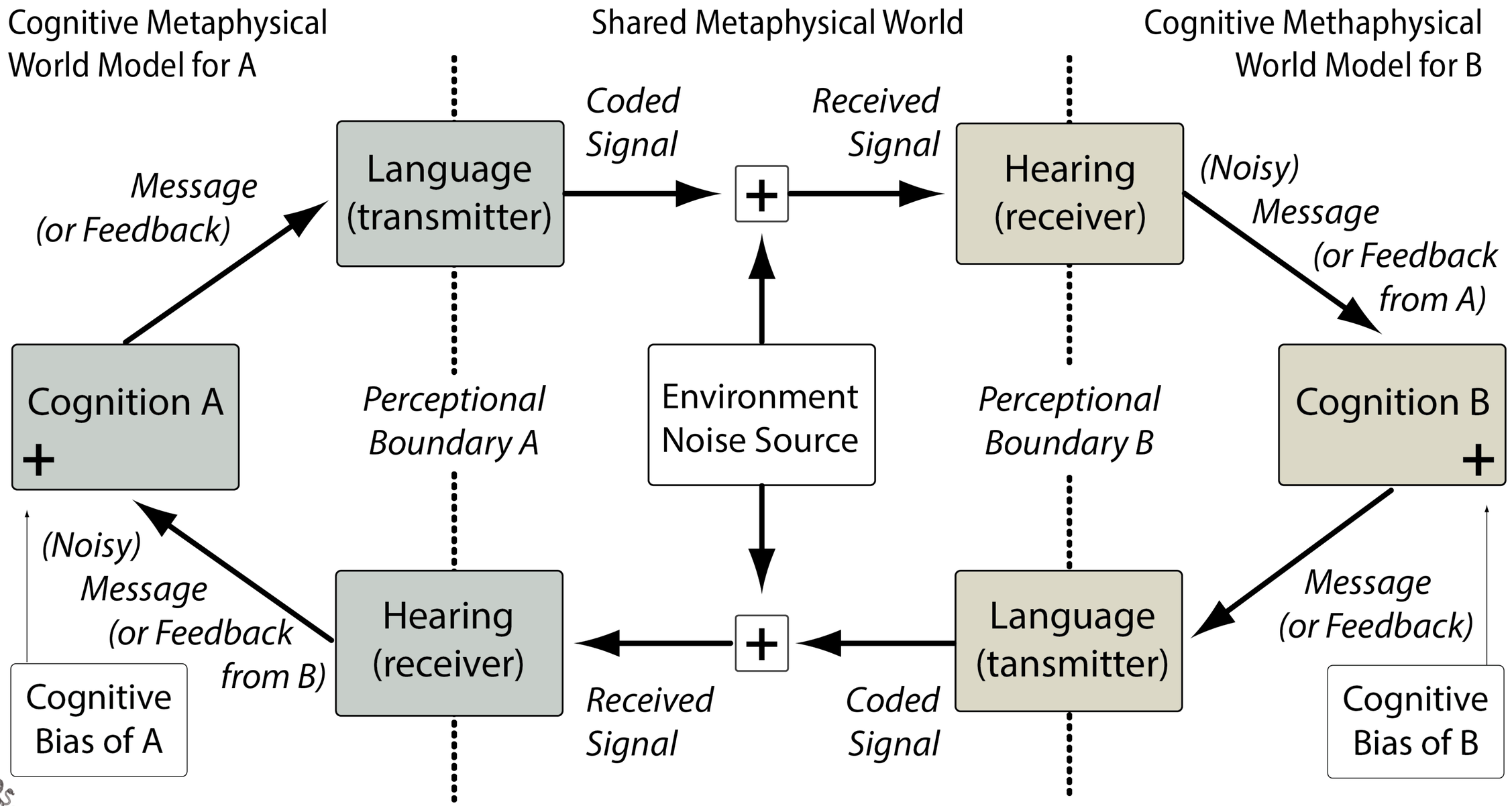
References:

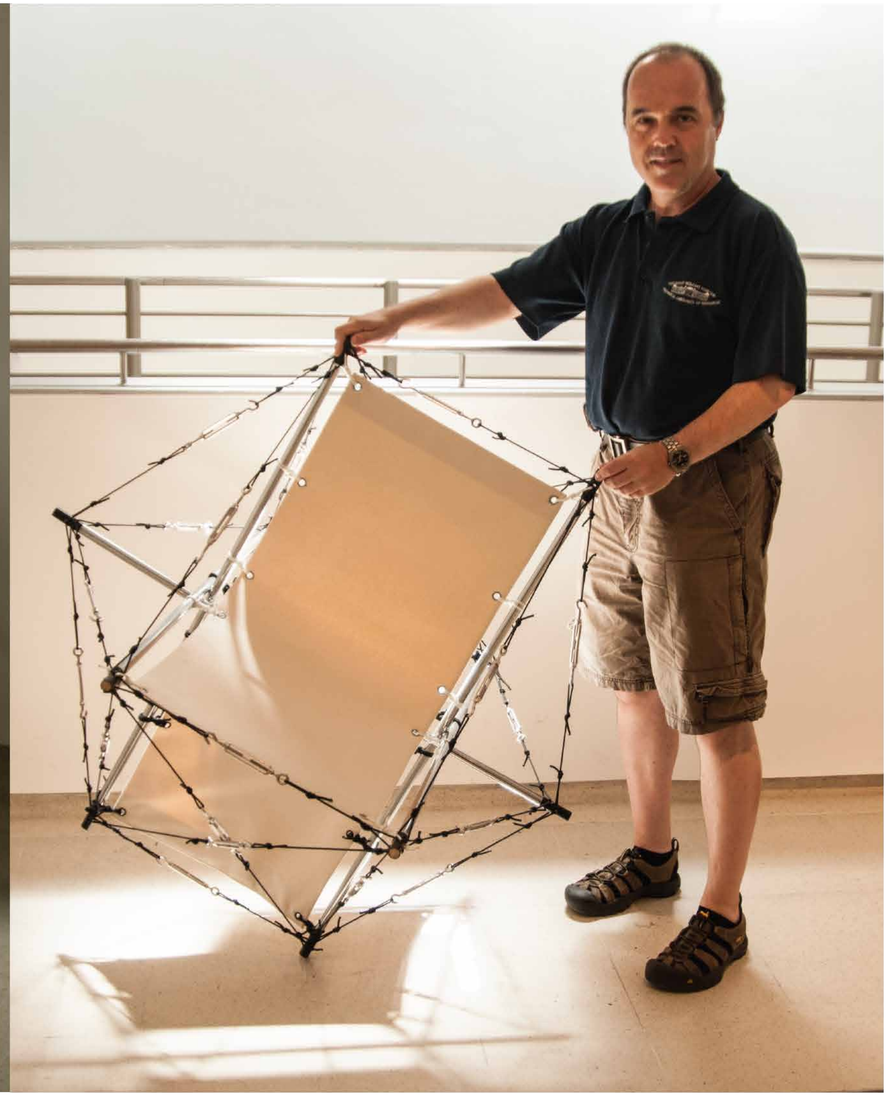
Wicked problems

- The problem is not understood until after the formulation of a solution.
- Wicked problems have no stopping rules, difficult to know when the problem is solved or solution is reached.
- Solutions to wicked problems are not right or wrong.
- Every wicked problem is essentially novel an unique.
- Every solution to a wicked problem is a “one shot operation”.
- Wicked problems have no given alternative solutions.

[Rittel & Webber, 1973] [Conklin, 2006]



[Balint & Hall, 2015a] with influences from [Shannon, 1948]



Cybernetic astronaut chair (tensegrity structure)

by T. Balint, 2016 [Balint & Hall, 2015a]

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"Expanding Boundaries" medal

"Al Seiff Memorial Award" medal

by T. Balint, 2016

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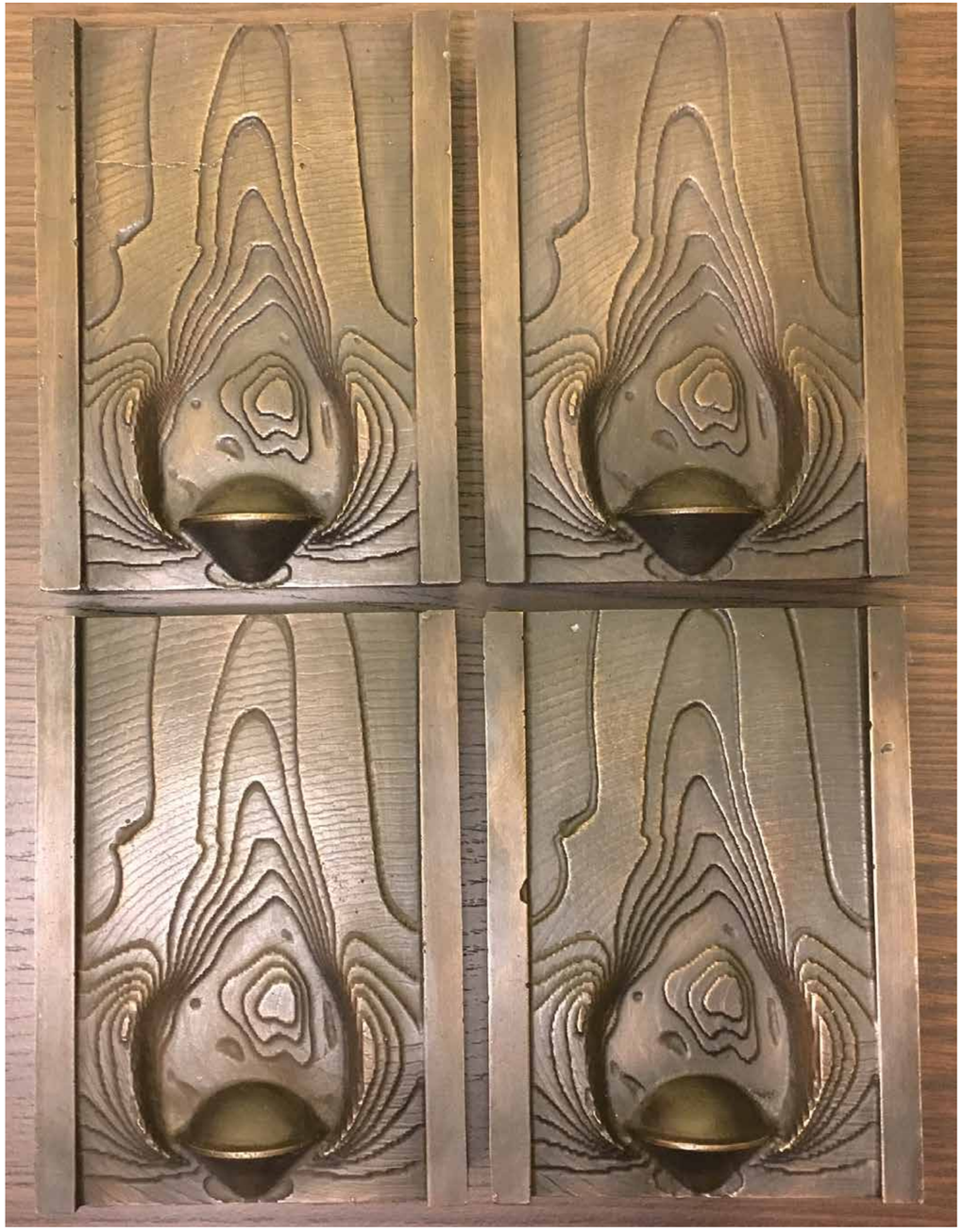

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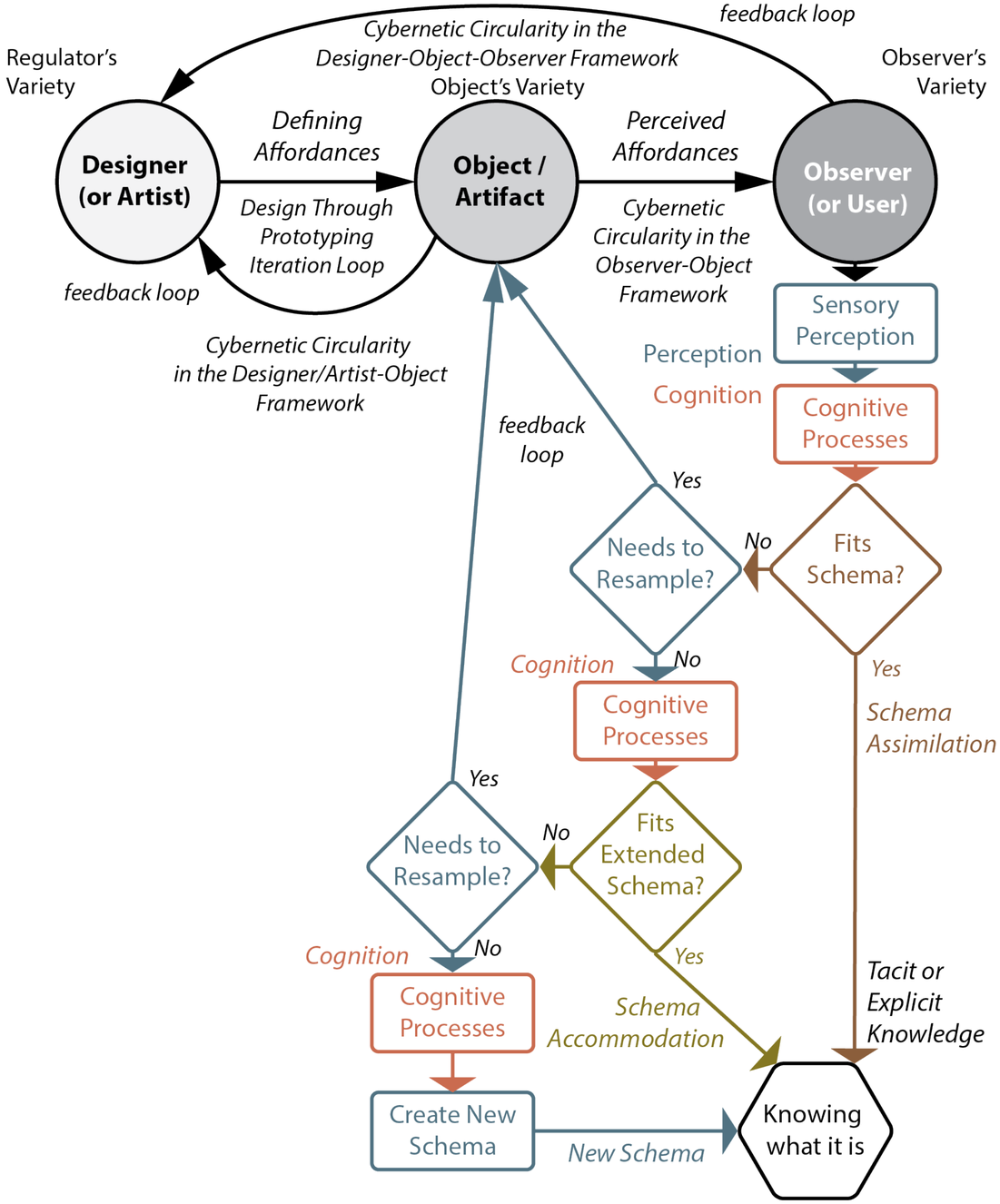
[Balint, 2016]

Galileo Flow Field artifacts (bronze & walnut)

This constructivist system consists of three actors:

- the Designer or Artist (as Regulator)
- the Object / Artifact
- the Observer or User

Built on concepts by
Wiener - cybernetics, circularity
Ashby - cybernetics, variety
Piaget - schema, cognition
Polanyi - tacit knowledge
Gibson - affordances
Norman - perceived affordances



[Balint & Hall, 2015b]