AI4CE - Automated Space Mission Design Concepts Generation with Reinforcement Learning

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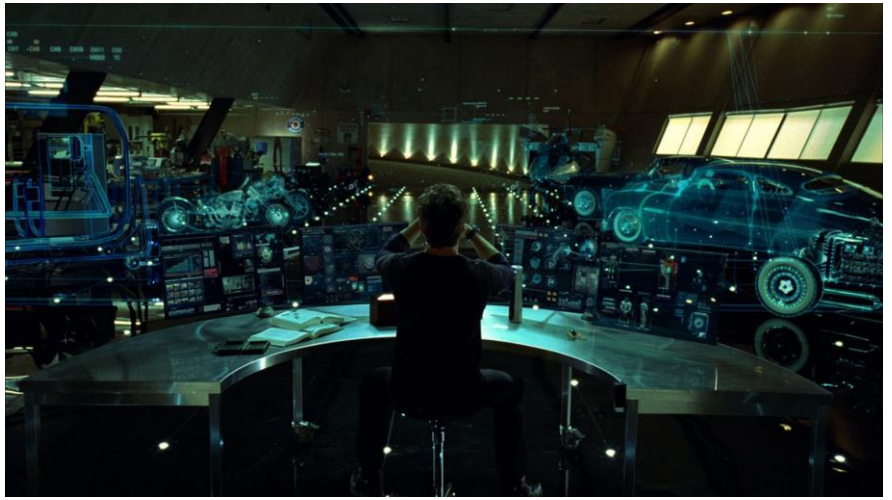

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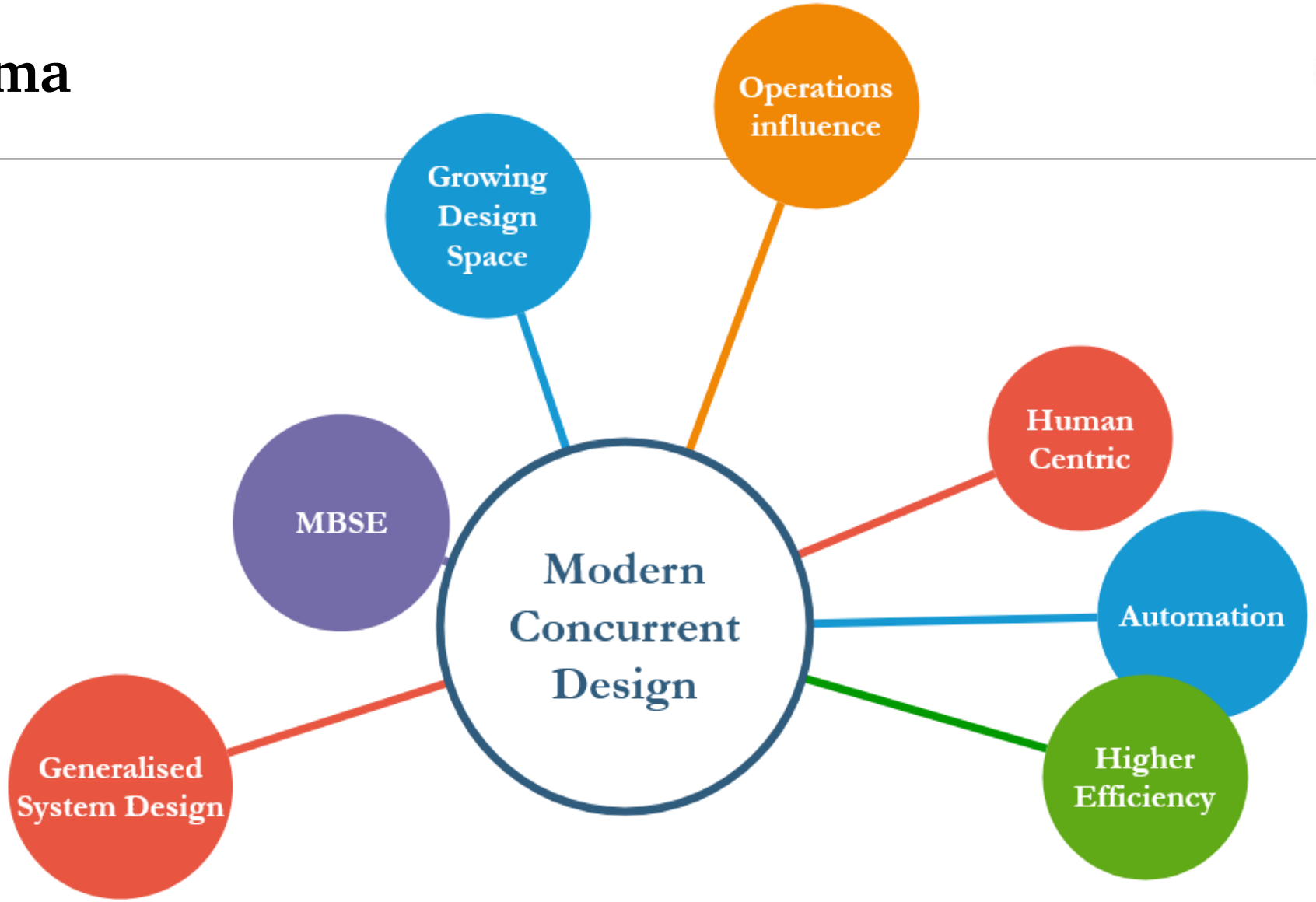
The Dilemma


Operations influence
Growing Design Space
MBSE
Modern Concurrent Design
Human Centric
Automation
Higher Efficiency
Generalised System Design

What would be the perfect solution?

J.A.R.V.I.S [2]

Functionality

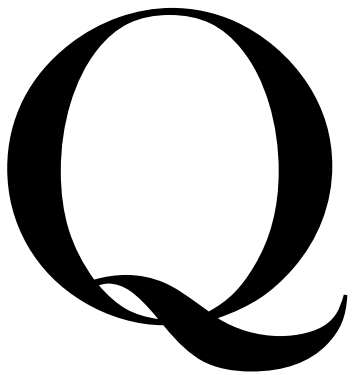
- General, automated design creation
- User-friendly and interactive
- Integration of the OPS experience

Integration

- Interactive CE integration
- MBSE-native

higher efficiency + MBSE integration

→ *A system that **helps** CE study experts **interactively** and **seamlessly,** to design the best possible concept design.*



What about using AI ?

State of the Art: AI for CE support

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	Top-Down	Bottom-Up
Creating Design knowledge based on	• Historical mission • Extracting knowledge	• System requirements • Text book calculations
Technology	• NLP • Expert Systems • Knowledge Base	• Combinatorics • Reinforcement Learning RL • DeepRL DRL

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Proposition: AI4CE

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- PhD Research Project
- Implementing AI-based bottom-up system creation
  - Deep Reinforcement Learning
  - Generalised system creation → Abstract building blocks
  - MBSE/CE integration
- Achieved in 3 modules:
  - DRL Concept Creator — DCC
  - MBSE/CE Integration — MBSE2DCC
  - OPS Experience Integration — OPS2Design

[3]

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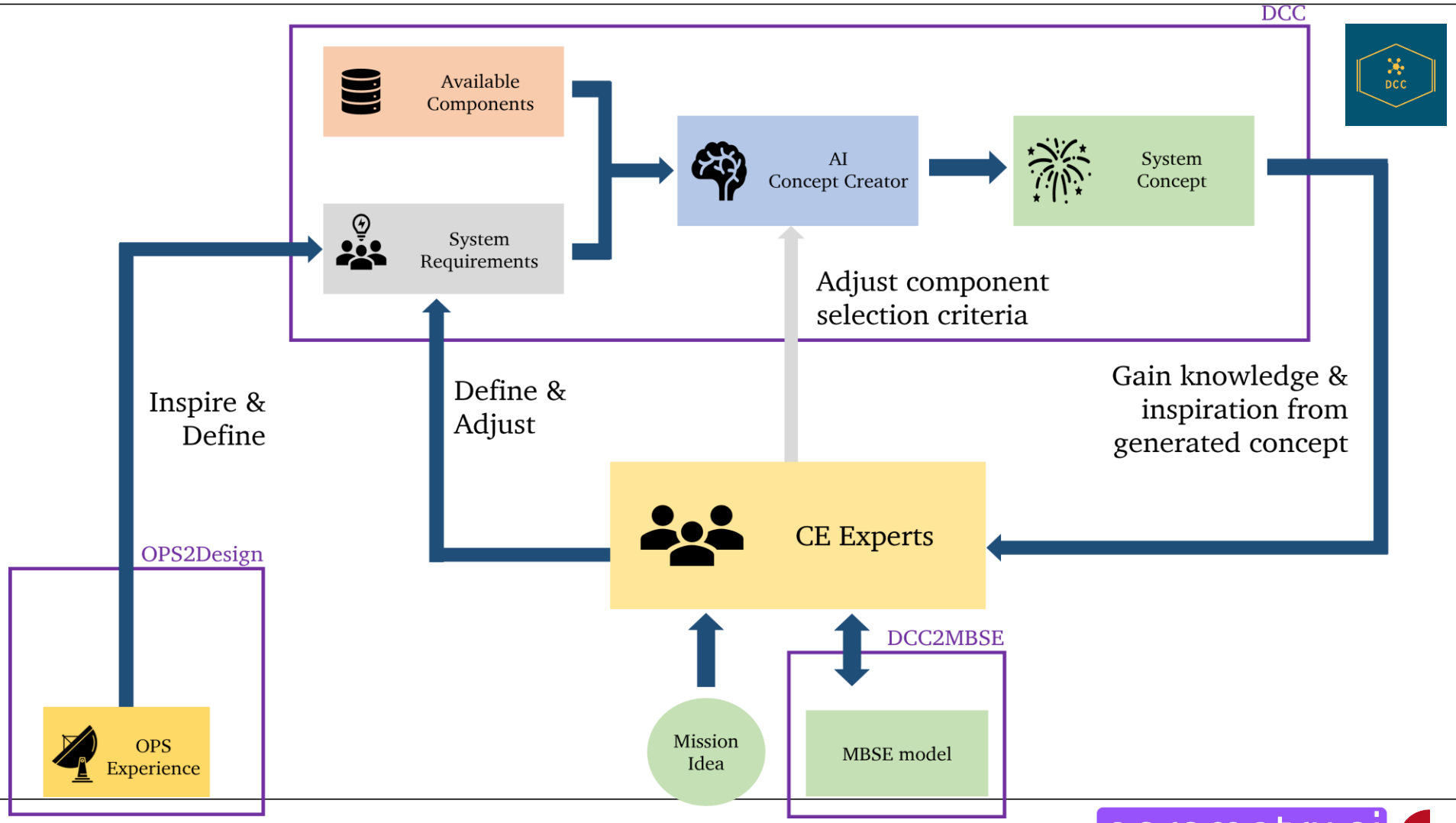
AI4CE Overview



[WIP] Research Questions

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1. Can **DRL** be used for concept creation? If yes, how?
2. What is the **potential** when applying bottom-up AI methods?
3. How to **model the knowledge base** of component interactions?
4. How to **integrate** automated concept creation in CE workflow?
5. How to **formalise** design requirements?
6. How can **OPS experience** be used for the design process?

Master

PhD

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Status Quo

2020 TU Delft: early steps and RL

2021 TU Darmstadt: progression

- First DRL implementation
- Prototype
- Simplified CubeSat
- Validation
- Open Source

2022 Preparation for PhD research

The Future

TECHNISCHE UNIVERSITÄT DARMSTADT

2022 Preparation for PhD research

2023 Research @ Parametry/TU Darmstadt

- **Analyse** and define model use cases
- **Model** abstract component interactions
- Designing and **implementing** the AI
- Defining **validation** criteria and use cases
- **Testing** design efficiency, usability and feasibility in CE sessions

2024/25

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Publications

IAC 2022 – Vision

AI4CE: BOTTUM-UP AI SUPPORT FOR CONCEPTUAL DESIGN

SECESA 2022 – MasterThesis

BUTTOM-UP AI-SUPPORT TO GENERATE CONCEPTUAL DESIGNS FOR CONCURRENT ENGINEERING STUDIES WITH DEEP REINFORCEMENT LEARNING

MBSE 2022 – MBSE Integration

Automated Space Mission Design Concepts Generation with Reinforcement Learning

SpaceOPS 2023 – OPS Integration

AI4CE - Closing the design-operation-loop: design, operate, learn, repeat

Where you can help me!

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- Modelling
- CE integration
- All things MBSE
  - SysML vs X
  - Import expert MBSE models
- Creation Validation

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Contacts

TECHNISCHE UNIVERSITÄT DARMSTADT

- AI Support for Conceptual Design
  - Concurrent Engineering, MBSE
  - AI, Deep Reinforcement Learning
  - Like Jarvis from Iron Man
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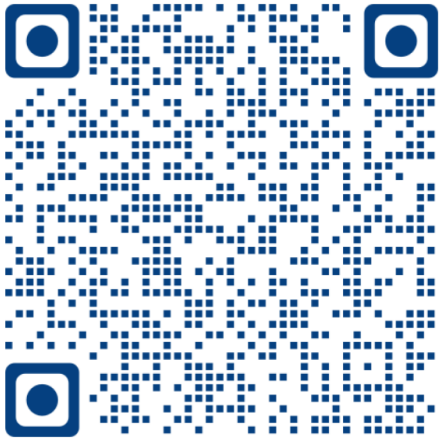
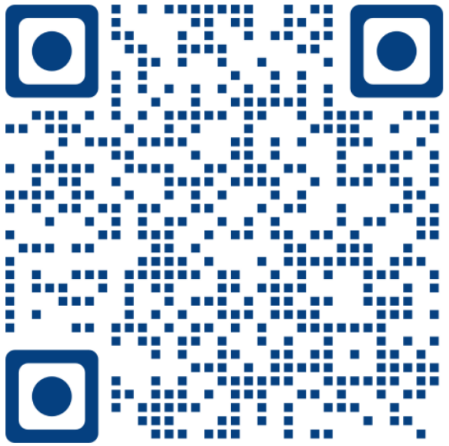


LinkedIn



Slides
Paper

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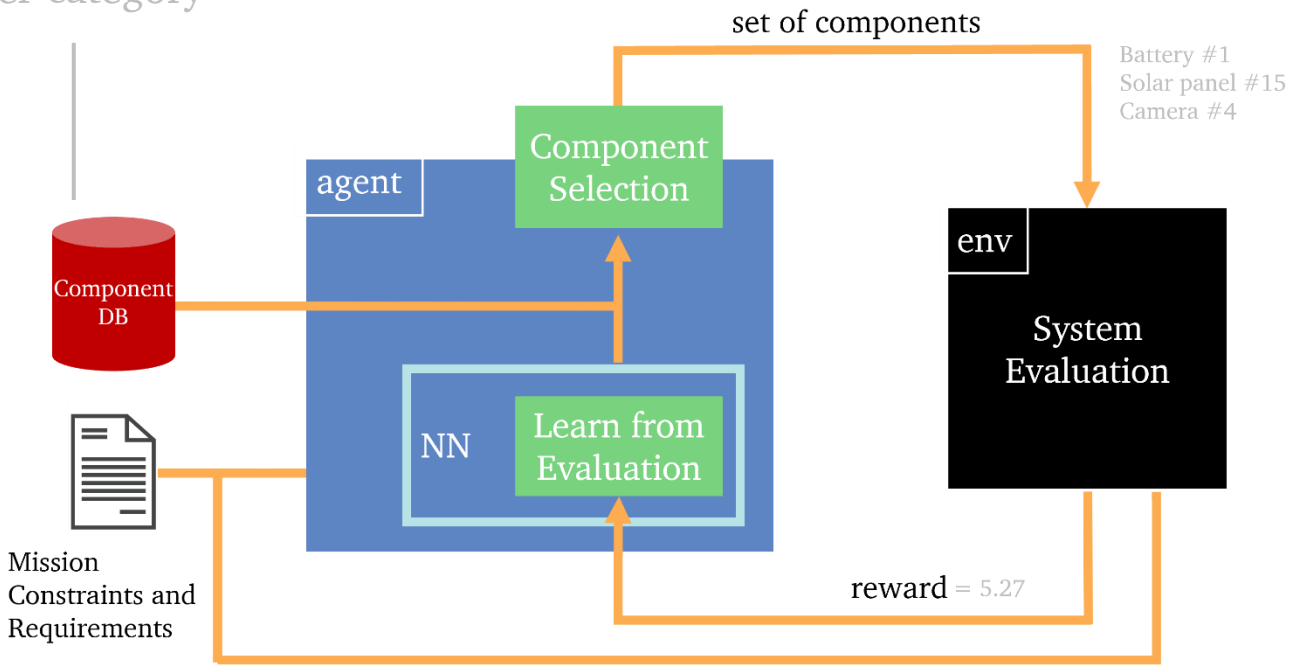
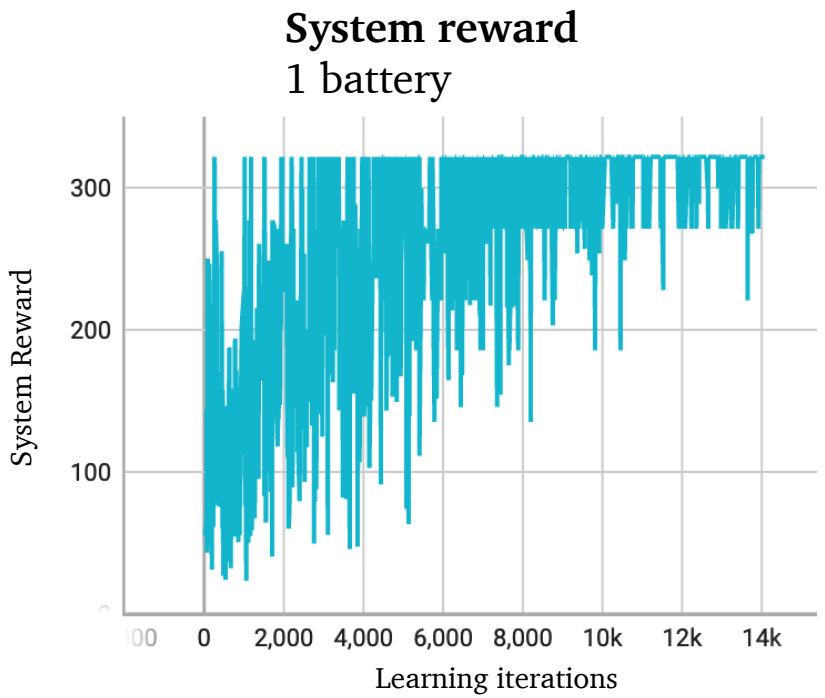
Resources

[1]DLR Report, Böning 2021, “The Current State of Research and Technology of Digitalization in the Space Industry” https://www.dlr.de/sc/en/desktopdefault.aspx/tabid-5135/8645_read-8374/
[2] Jarvis https://i.pinimg.com/originals/ec/9d/bc/ec9dbccee1ca0cc5c93af15032bb1d5c.jpg
[3] https://gitlab.com/jan-peter/drl-concept-creator
[4] EQuiSat https://dl.airtable.com/.attachments/bf8aadaf84b824b4ab8ebf997f3f7cd5/9f5d80eb/EQUISat_2.jpg

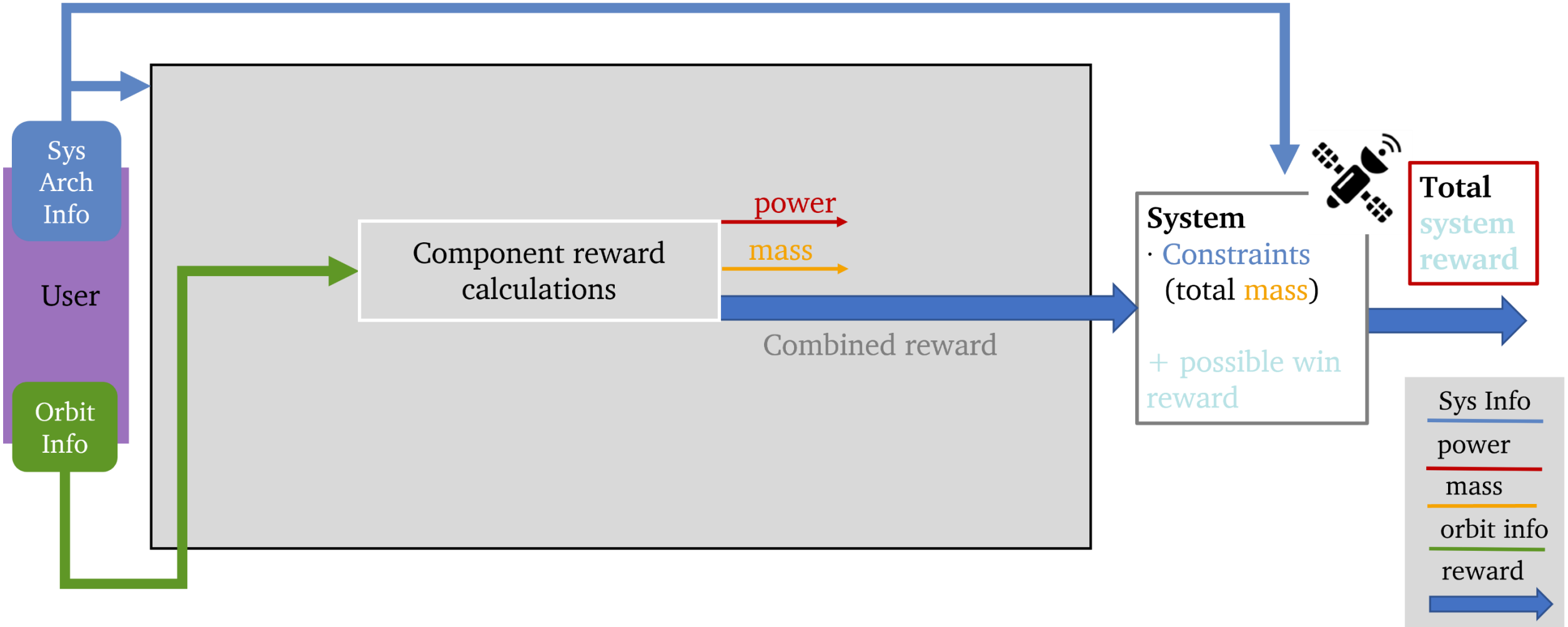
DRL Concept Creator

SatSearch WebShop
10s .. 100s components
per category





DCC Prototype: Reward Building



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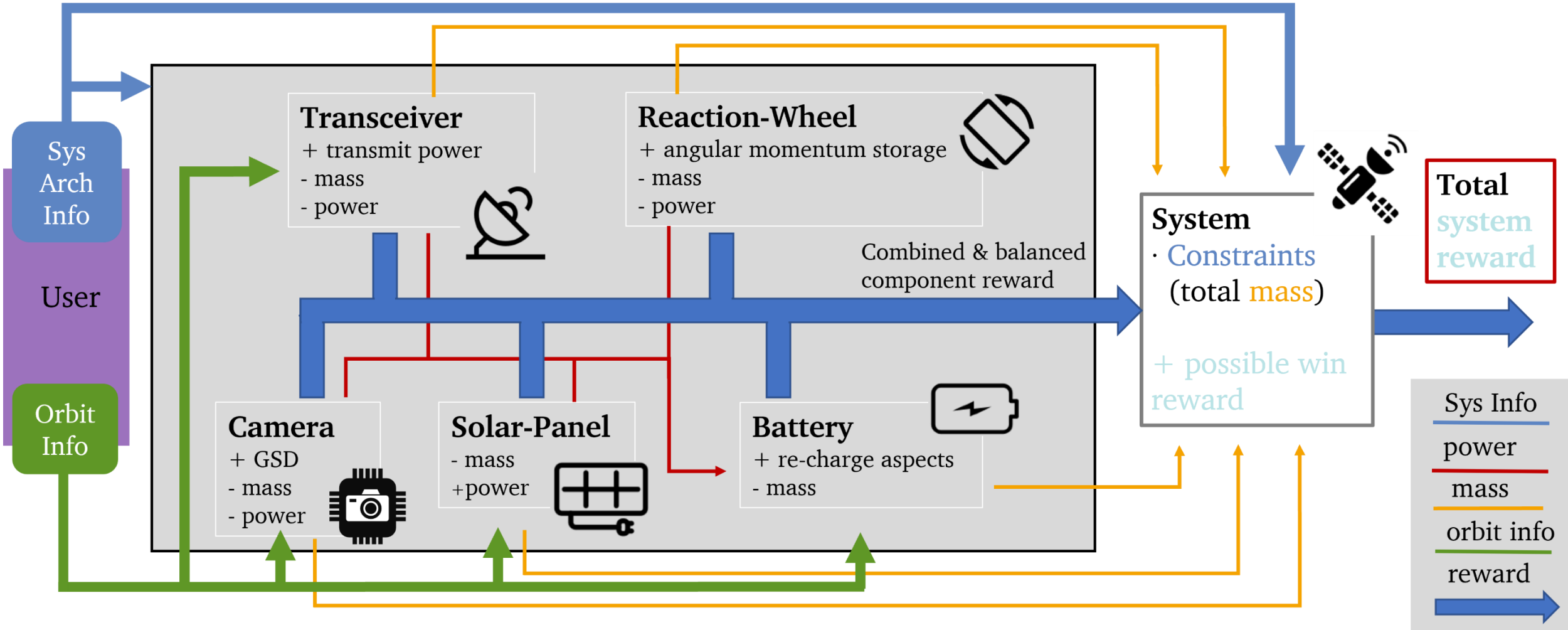

DCC Prototype: Validation

- Multiple global system configurations
- Multiple orbits
- Against
  - real-world missions
  - Brute-force combinatorics

1U=best case

→ Promising Results

EQUiSat

transceiver, solar panels

Batteries + payload + structure

[4]

AI tool	**EQUiSat**
1U solar panel	1U solar panel
mass = 800 g	mass = 1350 g
$P_{balance}$ =- 2.3 W	$P_{balance}$ = -5 W

$mass_{system}$	- 32 %
$P_{balance}$	- 54 %

→ Fitting within limitations
- Missing components
- Different database