AI4CE: Bottom-Up AI Support For Conceptual Design

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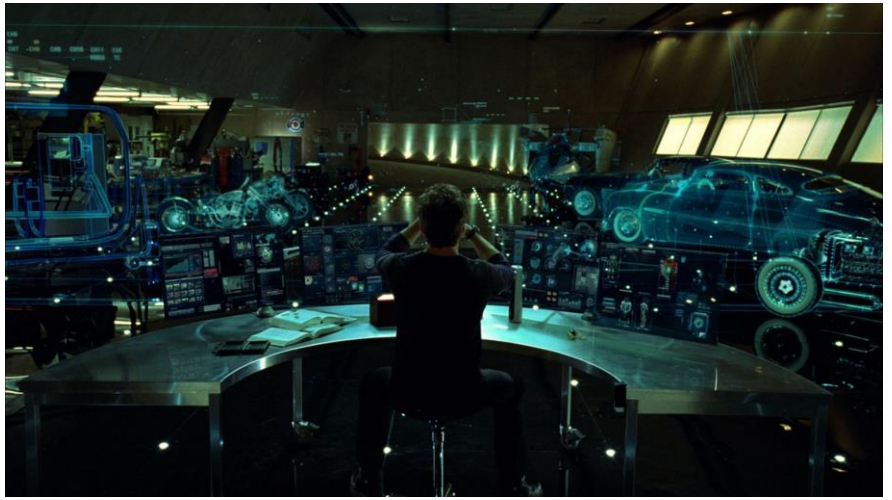

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AI Support for Concurrent Engineering

Support of CE studies through AI by

- providing valuable design knowledge
- automated
- integrated

What would be the perfect solution?

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

Functionality

- Automated System creation for any kind of system
- User-friendly and interactive

Integration

- Interactive CE integration
- MBSE-native

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

State of the Art

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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	• combinatorics • Reinforcement Learning RL • Deep RL DRL

Proposition: AI4CE

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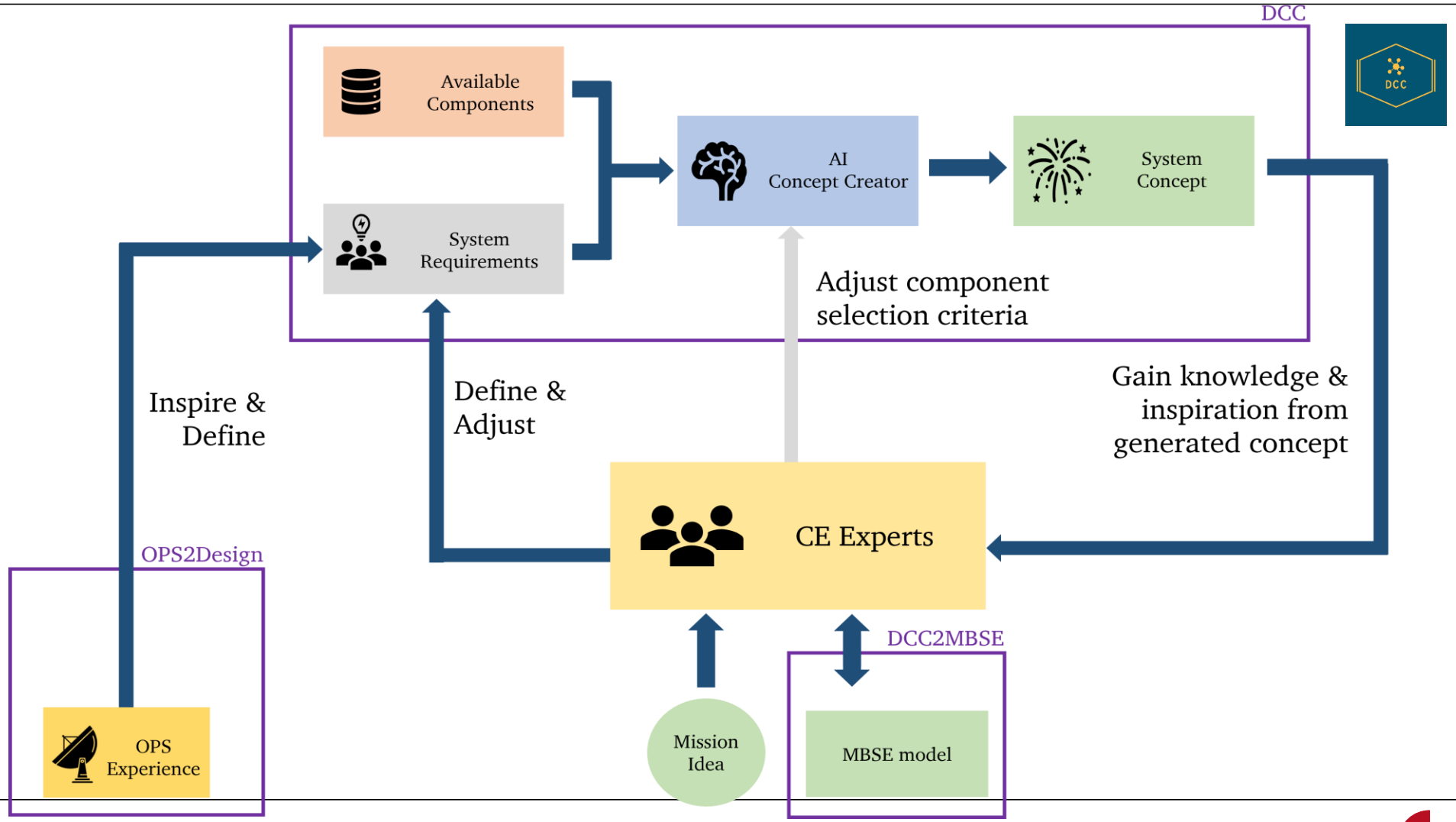
- PhD Research Project
- Implementing AI-based bottom up system creation
  - Deep Reinforcement Learning
  - Generalised system creation → Abstract building blocks
  - MBSE/CE integration
- Achieved in 3 modules:
  - DRL Concept Creator — DCC
  - MBSE/CE Integration — MBSE2DCC
  - OPS Experience Integration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

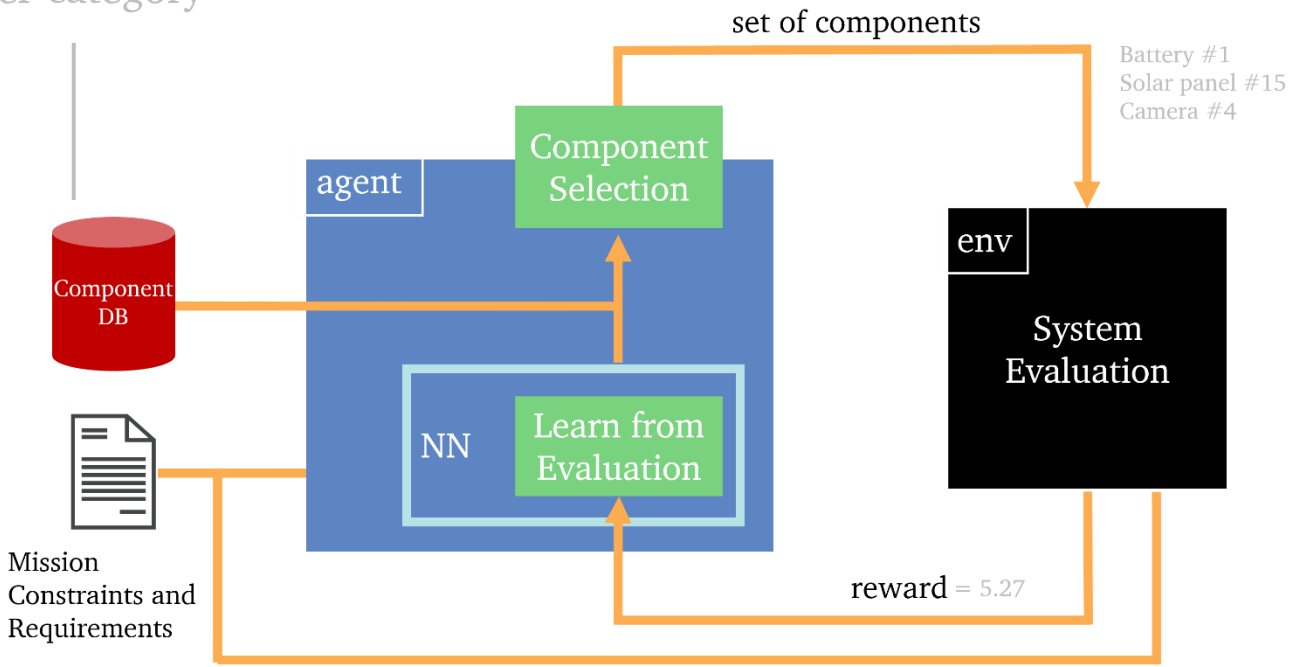
[3]

AI4CE Overview

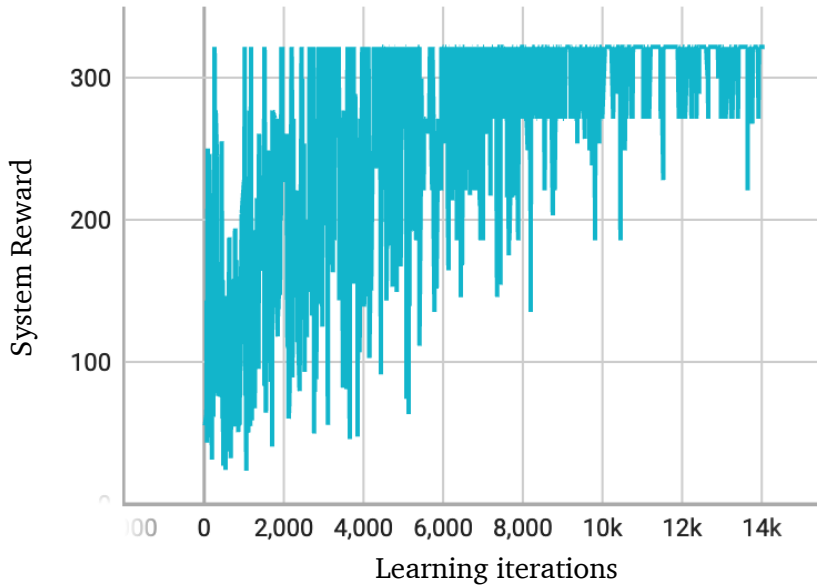


DRL Concept Creator

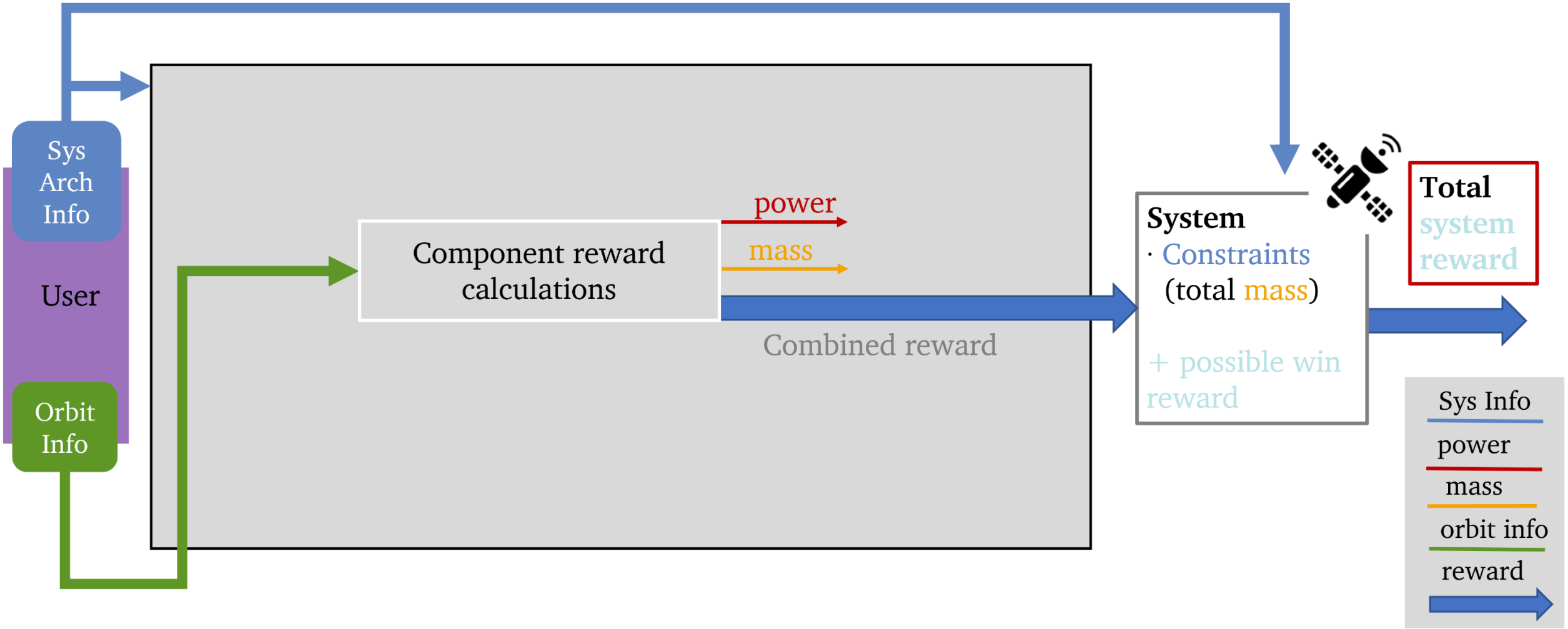
SatSearch WebShop
10s .. 100s components
per category



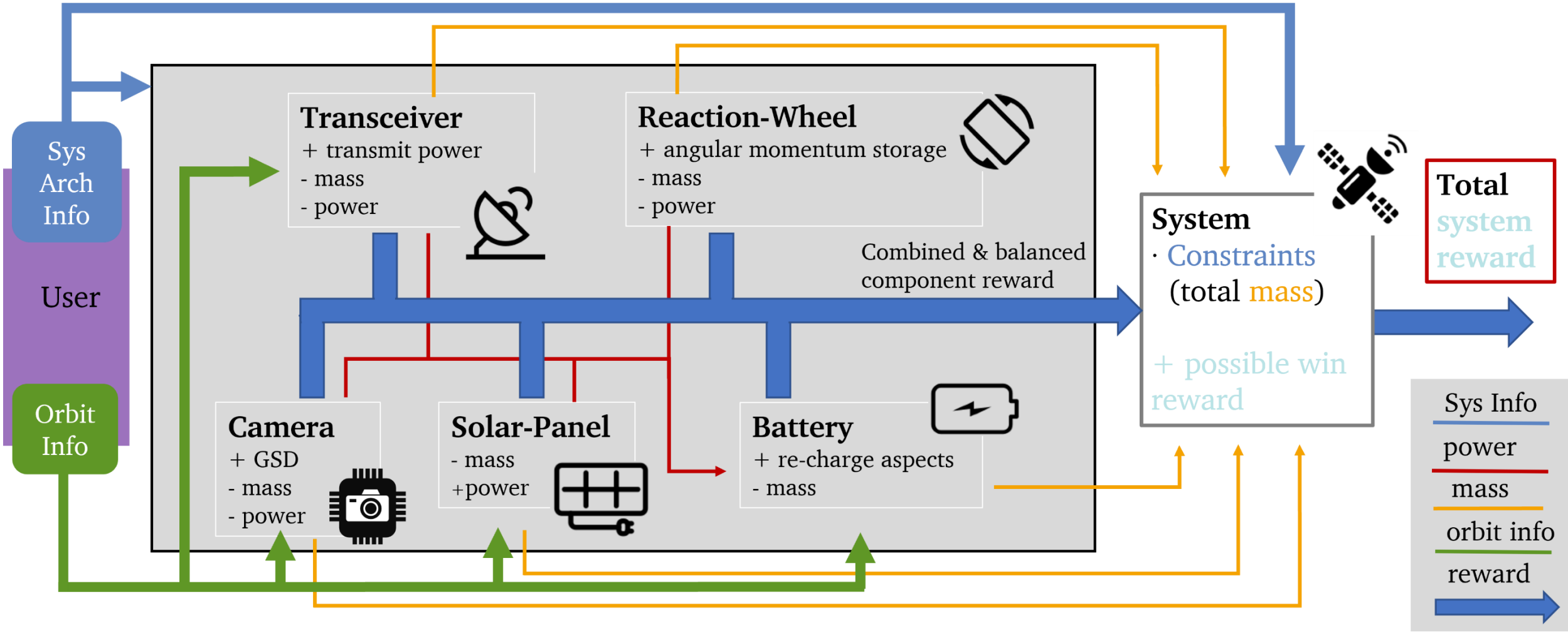
System reward
1 battery



DCC Prototype: Reward Building



DCC Prototype: Reward Building



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

[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

Status Quo

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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

Publications

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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

Contacts

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- AI Support for Conceptual Design
  - Concurrent Engineering, MBSE
  - AI, Deep Reinforcement Learning
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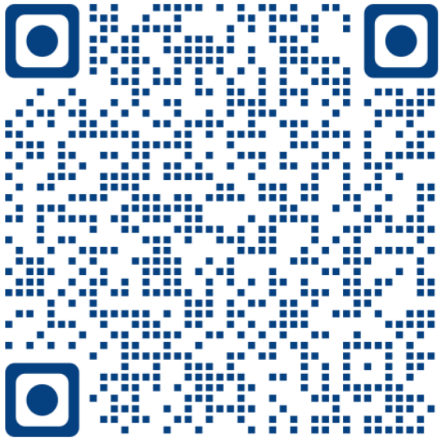
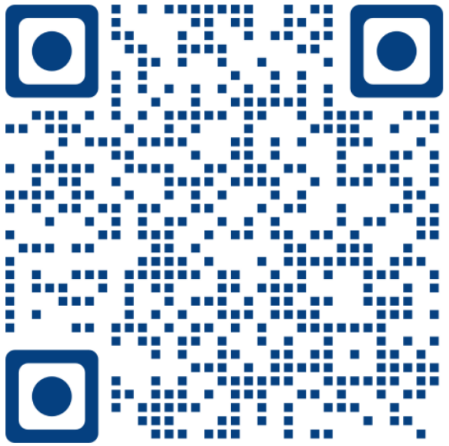


LinkedIn



Slides
Paper

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