32nd Annual INCOSE international symposium

hybrid event

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# Academic application of trade-off studies to support a CubeSat Project

www.incose.org/symp2022

# Contents

- Academic CubeSat Projects and Challenges
- Why Trade-off Studies?
- Trade-off Case Study
- Discussion
- Conclusion and Further Work

# Academic CubeSat Projects and Challenges

# What is a CubeSat?

- Standard format

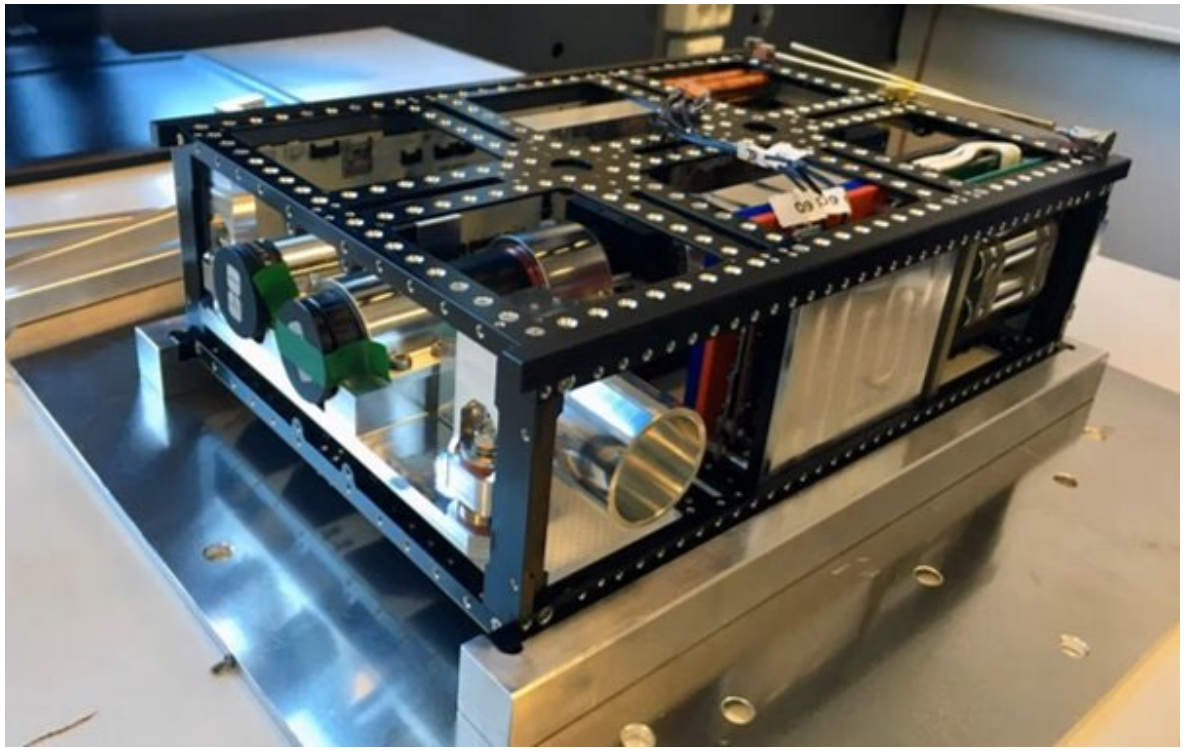
CubeSat Design Specification Rev. 14.1
The CubeSat Program, Cal Poly SLO

| Document Classification | |
|---|---|
| X | Public Domain |

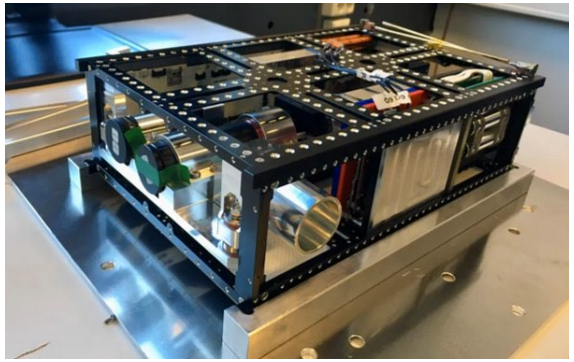
CubeSat Design Specification
(1U – 12U)
REV 14.1
CP-CDS-R14.1

CUBESAT

Cal Poly – San Luis Obispo, CA



# What is a CubeSat?



- In-orbit demonstration
- Engineering education
- Scientific research

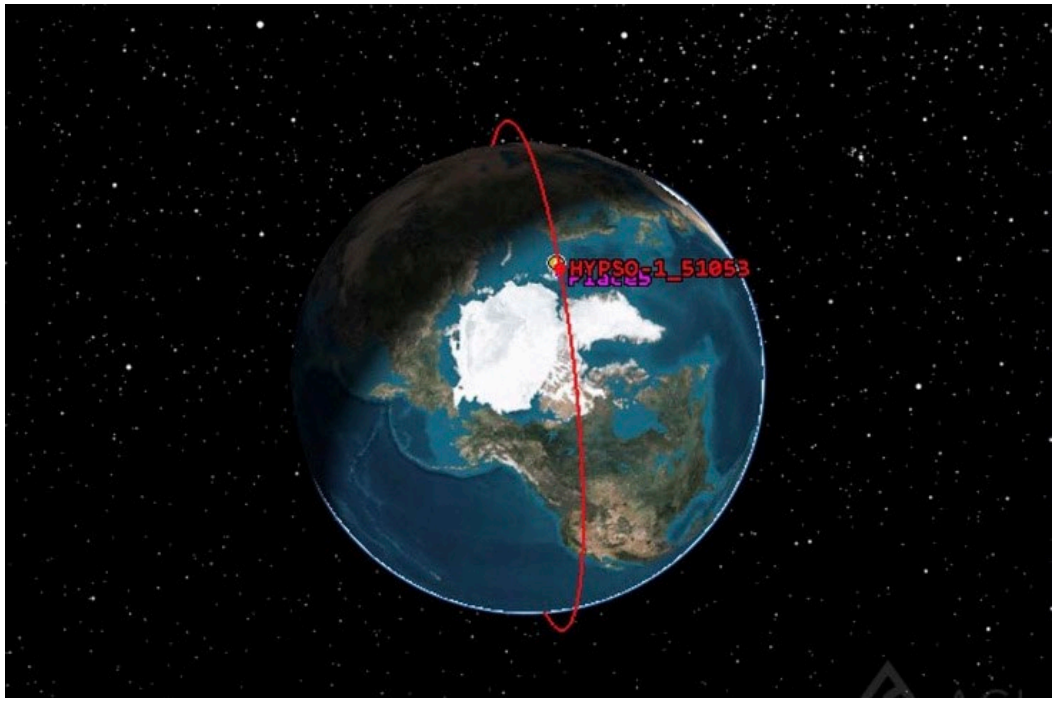



Illustration: Roger Birkeland

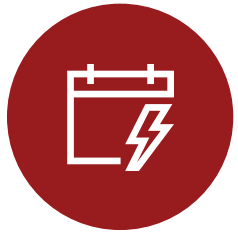
# Challenges for Academic CubeSat Projects

KNOWLEDGE MANAGEMENT

LACK OF FORMAL METHODS FOR RISK AND FAILURE ANALYSIS

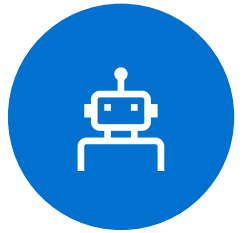


INCORPORATING LESSONS LEARNED SYSTEMATICALLY



SCHEDULE OVERRUNS AND LACK OF FUNDING

LITTLE TESTING AT SYSTEM LEVEL



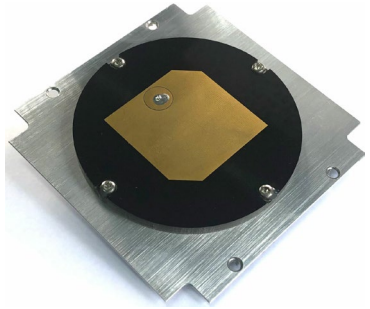
SUCCESSFUL INTEGRATION OF CUBESAT ENGINEERING TASKS INTO THE CURRICULUM

# Why Trade-off Studies?

# Decision-making and Trade-off Studies

- Assumptions
- Rationale
- Tacit and explicit knowledge

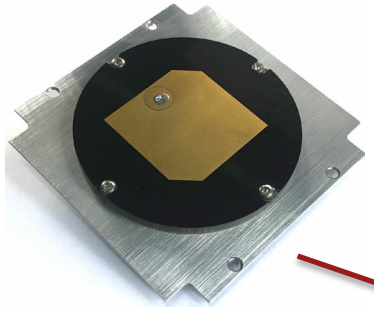
# Decision-making and Trade-off Studies



- Assumptions
- Rationale
- Tacit and explicit knowledge

https://www.cubesatshop.com/product/isis-s-band-patch-antenna/
https://nanoavionics.com/cubesat-components/cubesat-uhf-antenna/

# Decision-making and Trade-off Studies



- Assumptions
- Rationale
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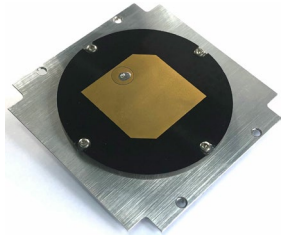
# Decision-making and Trade-off Studies



- Trade-off criteria
  - Cost
  - Power budget
  - Link budget
  - Availability

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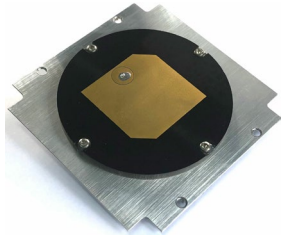
# Decision-making and Trade-off Studies



- Trade-off criteria
  - Cost
  - Power budget
  - Link budget
  - Availability
- Challenges
  - Interrelated alternatives
  - Missing alternatives
  - Communication and documentation
  - Intuition vs. formalism

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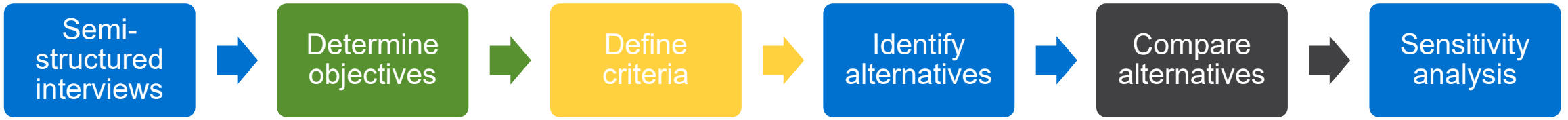
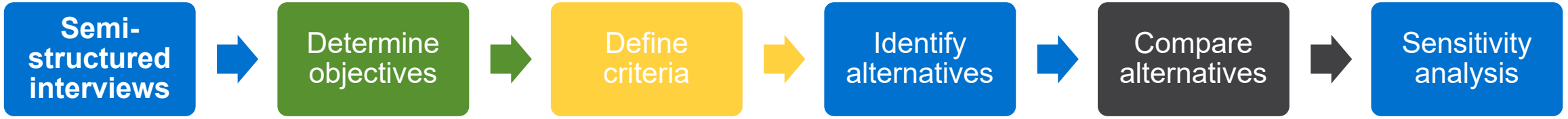
# Trade-off Case Study

# Method

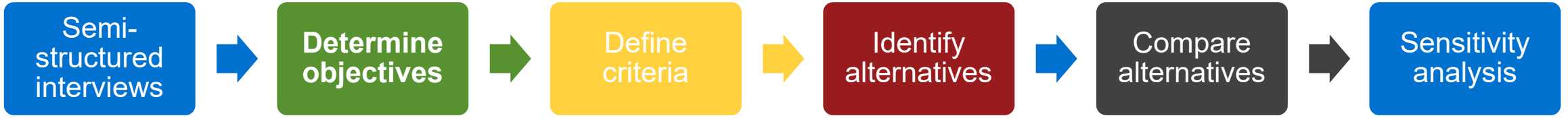

Semi-structured interviews
Determine objectives
Define criteria
Identify alternatives
Compare alternatives
Sensitivity analysis

# Method - interviews




- What are the goals and responsibilities of your team?
- What is the main objective for your team?
- What responsibilities does your team have to the project and other teams?
- Which software programs does your team use?
- How do your team members store their data and their work?
- How do the team members share their data with other teams and which other teams need access to your data?

# Method - objectives



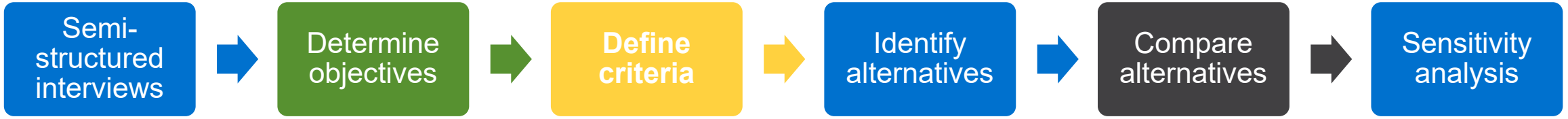

O1: Improve communication

O2: Improve design decisions

O3: Improve understanding

O4: Improve long-term achievements of the project

# Method - criteria




- C1: Low cost
- C2/C3: Existing SysML/SysML 2.0
- C4: Community
- C5: Usability
- C6: Interoperability

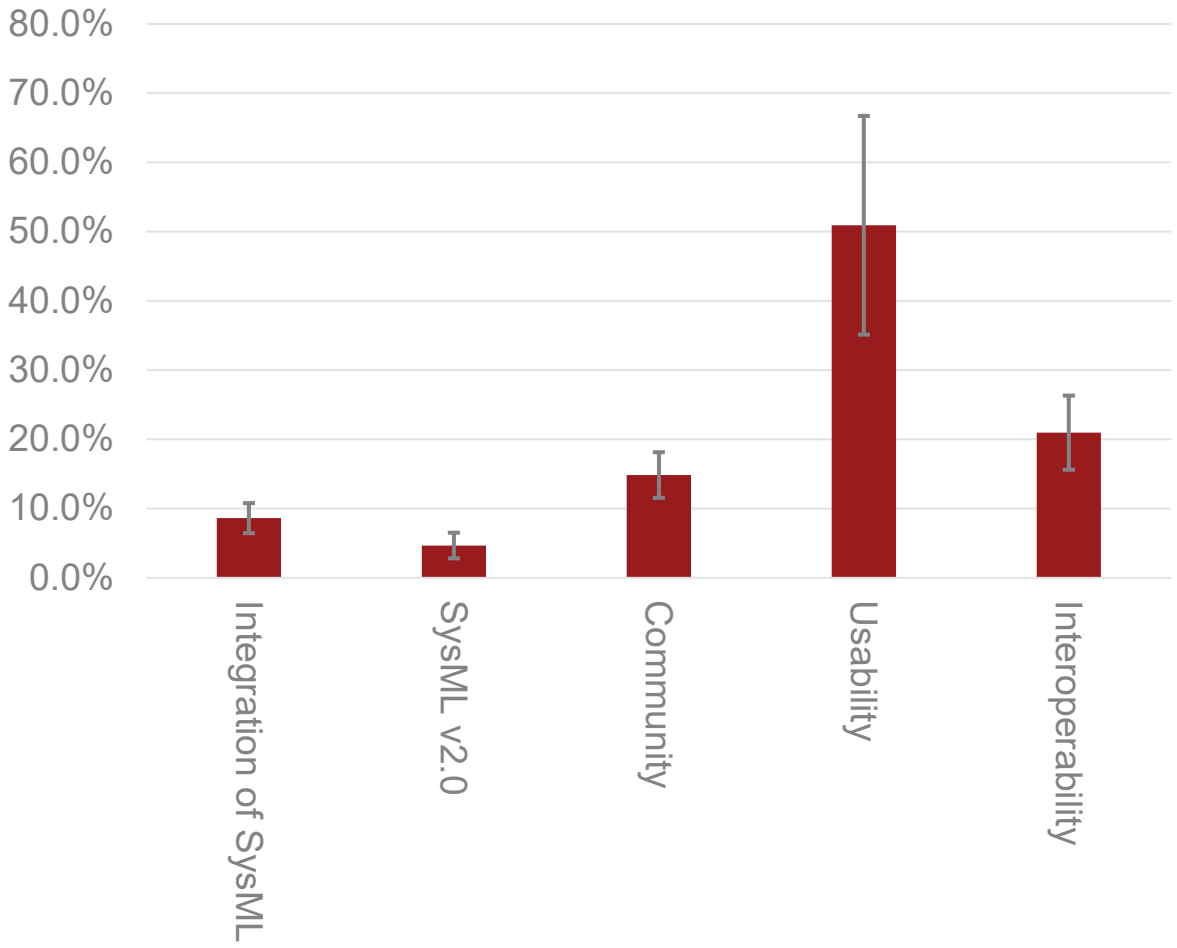
# Analytical Hierarchy Process

- Evaluating importance of each criterion
- Pairwise ranking

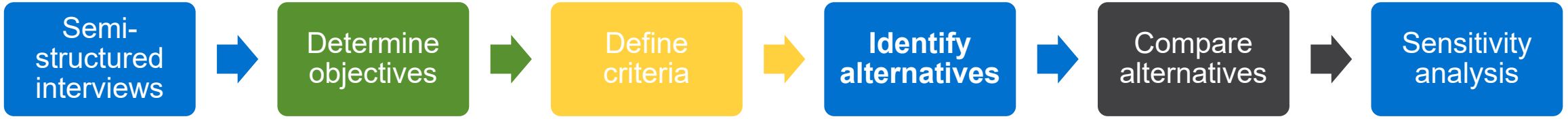
| | Integration of SysML | SysML v2.0 | Community | Usability | Interoperability |
|---|---|---|---|---|---|
| **Integration of SysML** | 1 | 2 5/7 | 5/9 | 1/6 | 1/3 |
| **SysML v2.0** | 3/8 | 1 | 2/9 | 1/6 | 1/4 |
| **Community** | 1 7/9 | 4 1/2 | 1 | 2/7 | 5/9 |
| **Usability** | 6 1/8 | 6 3/7 | 3 3/5 | 1 | 3 5/8 |
| **Interoperability** | 3 1/6 | 4 1/7 | 1 4/5 | 2/7 | 1 |

# Analytical Hierarchy Process

- Evaluating importance of each criterion
- Pairwise ranking

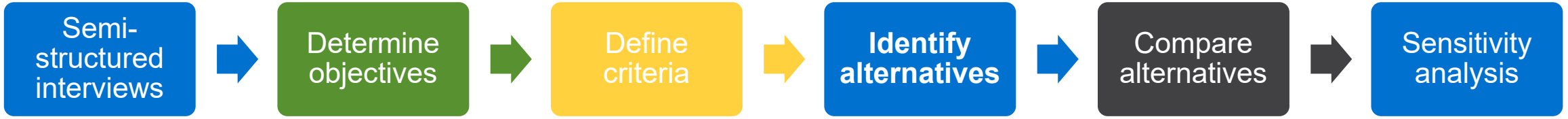


# Method – identify alternatives




A1. Capella (open-source) by PolarSys/Thales/Eclipse Foundation
A2. Modelio (open-source) by Modeliosoft
A3. Papyrus (open-source) by Eclipse Foundation
A4. Visual Paradigm by Visual Paradigm
A5. Matlab Simulink and System Composer by The MathWorks
A6. Cameo Systems Modeler by Dassault Systèmes
A7. CORE by Vitech Corporation
A8. GENESYS by Vitech Corporation
A9. Wolfram SystemModeler by Wolfram Research
A10. Enterprise Architect by Sparx System
A11. Innoslate by Innoslate
A12. Rational Rhapsody by IBM
A13. Scade by ANSYS
A14. MagicDraw by Dassault Systèmes
A15. Microsoft Visio by Microsoft
A16. Windchill Modeler by PTC

# Method – identify alternatives

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Lack of readily available information

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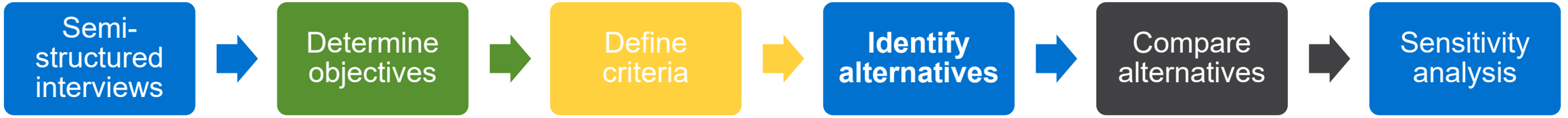
# Method – identify alternatives

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C1 cost criterion

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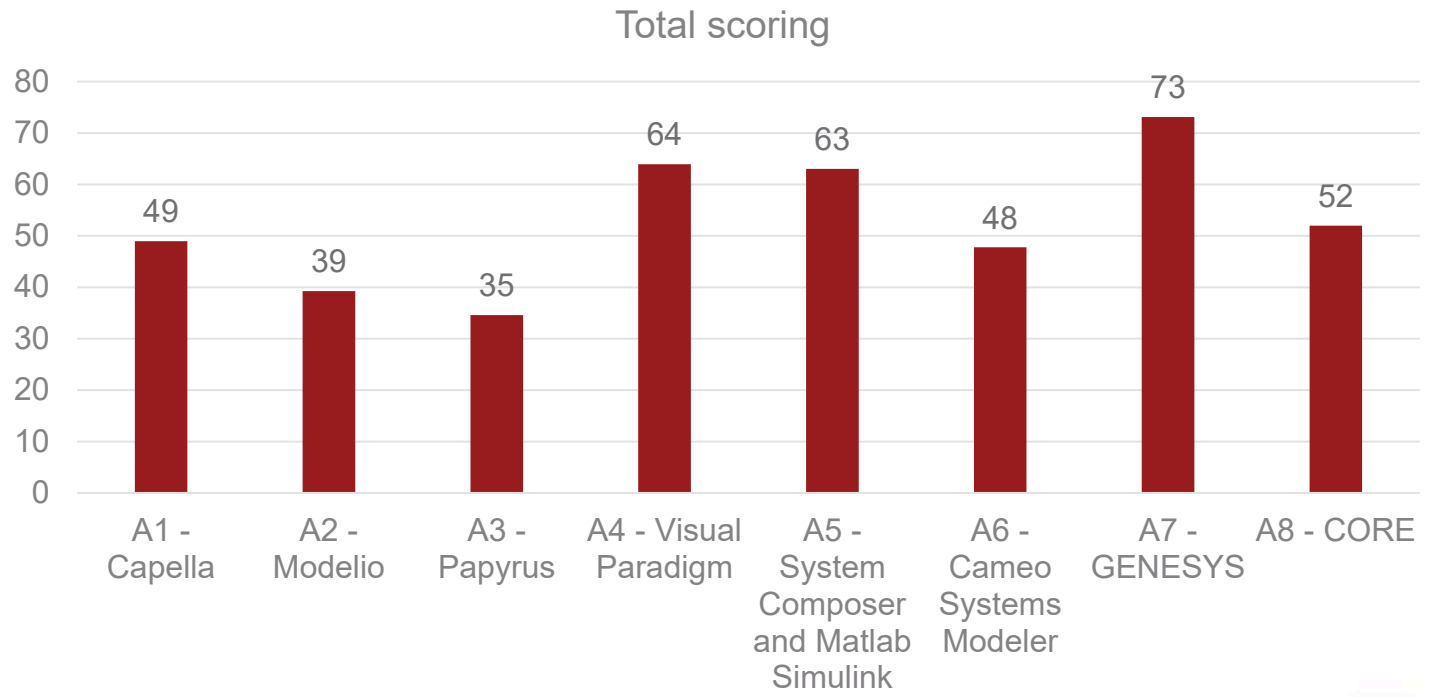
# Method – compare alternatives

Semi-structured interviews → Determine objectives → Define criteria → Identify alternatives → **Compare alternatives** → Sensitivity analysis

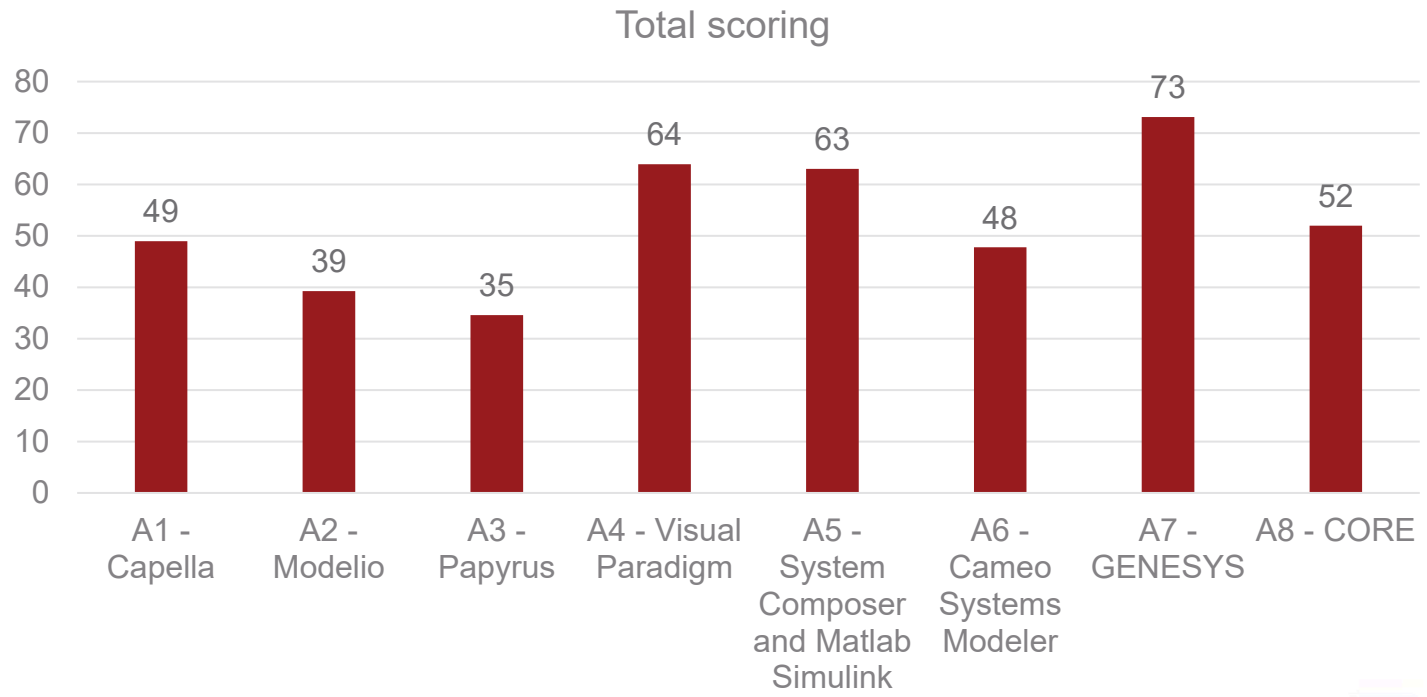
- Based on available documentation



# Method – sensitivity analysis

Semi-structured interviews → Determine objectives → Define criteria → Identify alternatives → Compare alternatives → **Sensitivity analysis**

- Setting each criterion to zero
- Usability set to zero affects the result:
  - Modelio wins



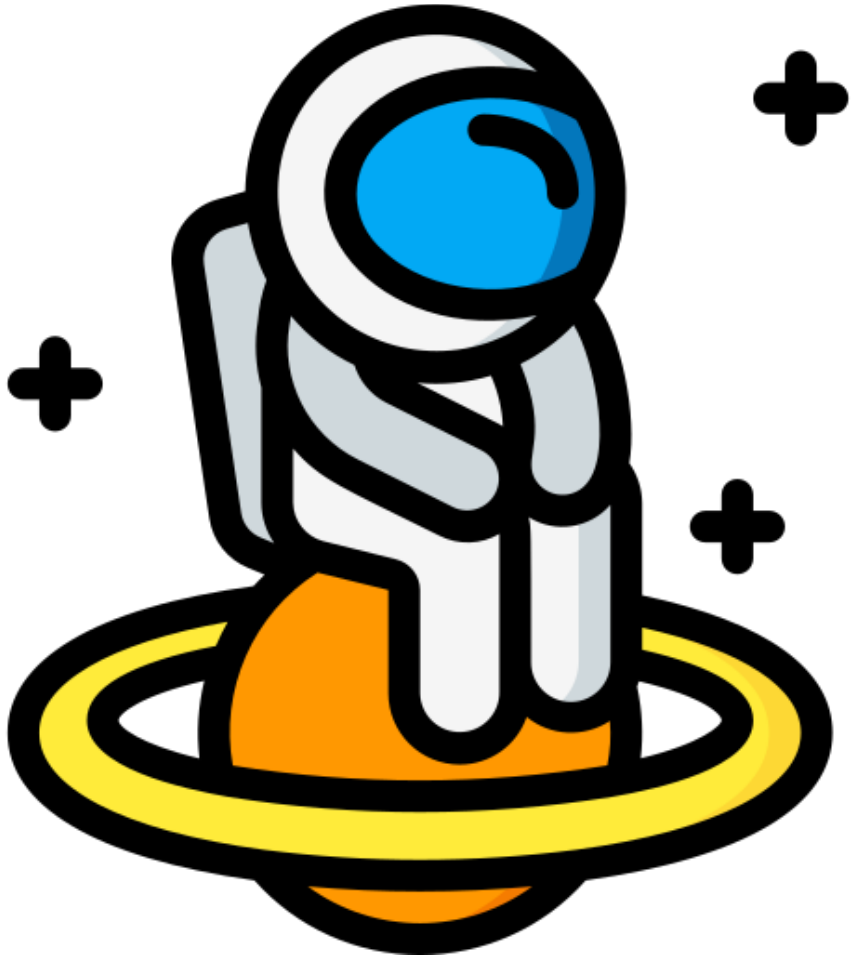
# Discussion

# Limitations

- Selection of alternatives
  - Identifying options
  - Lack of documentation
- Selection of objectives and criteria

# Conclusion and Further Work

# Conclusion



- Open-source vs. licenses
- Selecting and making a decision is not enough to make it happen
  - Need adoption in project organization
- CubeSat System Reference Model
  - Architecture for starting MBSE for CubeSats

# Further Work

- Effect of HYPSO project on students' Systems Engineering skills
  - And MBSE adoption in future workplaces
- Measuring the «usability» of selected tool
  - Possible to characterize what «usability» means?
- Revisiting the trade-off at multiple phases to see if the result changes

Evelyn.Livermore@gmail.com

# Thank you for listening

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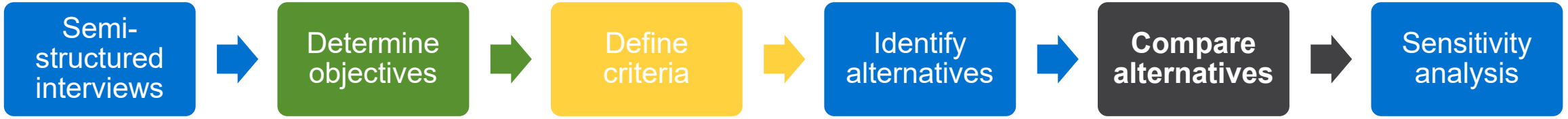
# Method – compare alternatives




- Based on available documentation

| Criterion/alternative | A1 | A2 | A3 | A4 | A5 | A6 | A7 | A8 |
|---|---|---|---|---|---|---|---|---|
| C2 – Integration of SysML 2.0 | 20 | 60 | 30 | 20 | 100 | 30 | 100 | 100 |
| C3 – Plan for SysML 2.0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 0 |
| C4 – Community | 50 | 50 | 30 | 60 | 70 | 20 | 50 | 50 |
| C5 – Usability | 70 | 40 | 50 | 80 | 70 | 50 | 70 | 25 |
| C6 – Interoperability | 20 | 30 | 10 | 60 | 40 | 80 | 80 | 50 |