CanSat 2021
Preliminary Design Review (PDR)

Team 5 - MapleCan:

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Presentation Outline

- Team and Mission
- The MapleCan
- Budgets
- CanSat Integration and Test Planning
- Conclusion
- PDR data package

Team and Mission

- Team Organigram
- Mission Statement
- Launch ConOps

Team Organization

Filip Slezák
Mechatronics engineer

ROB MA1 (SE minor)

Pierre Groslambert
CAD engineer

ROB MA3 (Space Tech.)

César Toussaint
Composite engineer

GM MA1 (Space Tech.)

Christopher Hémon
Payload engineer

ROB MA1 (SE minor)

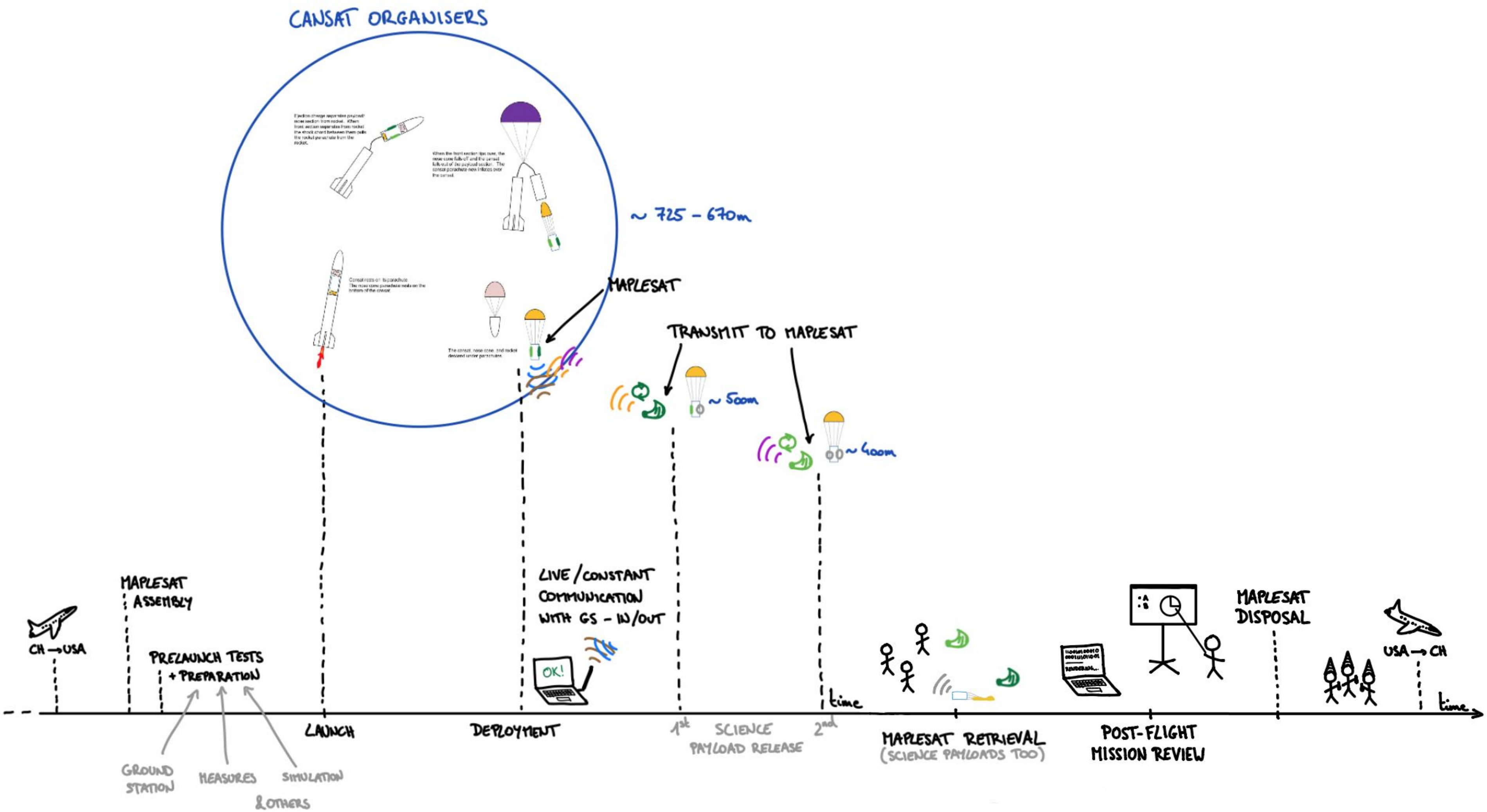
Mathieu Udriot
Electronics engineer

MT MA3 (Space Tech.)

Mission Statement

- **Map the air temperature as a function of the altitude.**
- **Compare GPS vs barometric altitude measure.**
- **Learn more about the development of a space project.**

Mission Concept of Operations

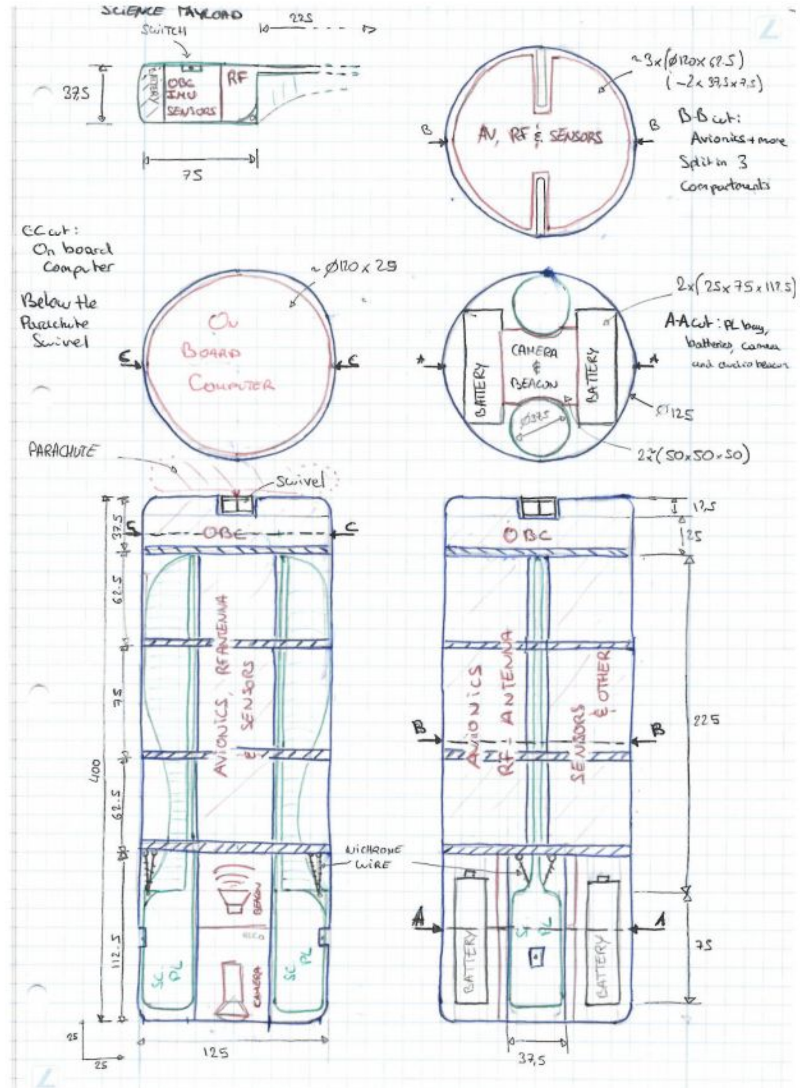


The MapleCan

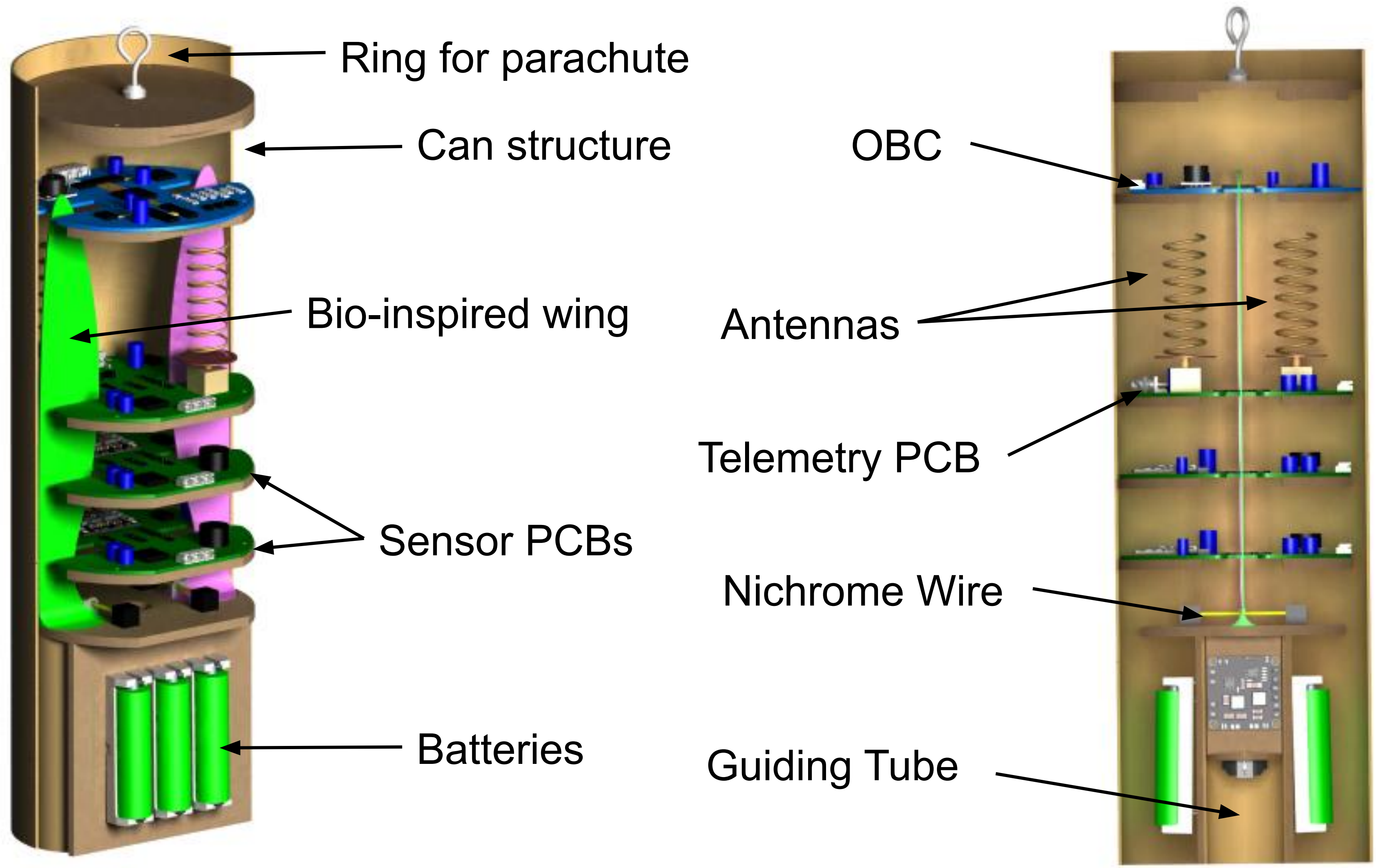
- System Overview
- Subsystems Descriptions
- Concept Design

System Overview

Mission (L1)	Systems (L2)	Subsystems (L3)	Explanation
CSC			CanSat Competition
ALL			All systems
↪	MC		MapleCan Satellite
↪	↪	AV	Avionics
↪	↪	PWS	Power Supply
↪	↪	COM	Telecommunications
↪	↪	PRM	Payload Release Mechanism
↪	↪	RE	Recovery
↪	↪	VID	Video Camera
↪	SP		Science Payloads
↪	↪	PWS	Power Supply
↪	↪	COM	Telecommunications
↪	↪	RE	Recovery
↪	↪	AV	Avionics
↪	GS		Ground Station
↪	↪	GSW	Ground Software
↪	↪	COM	Telecommunications

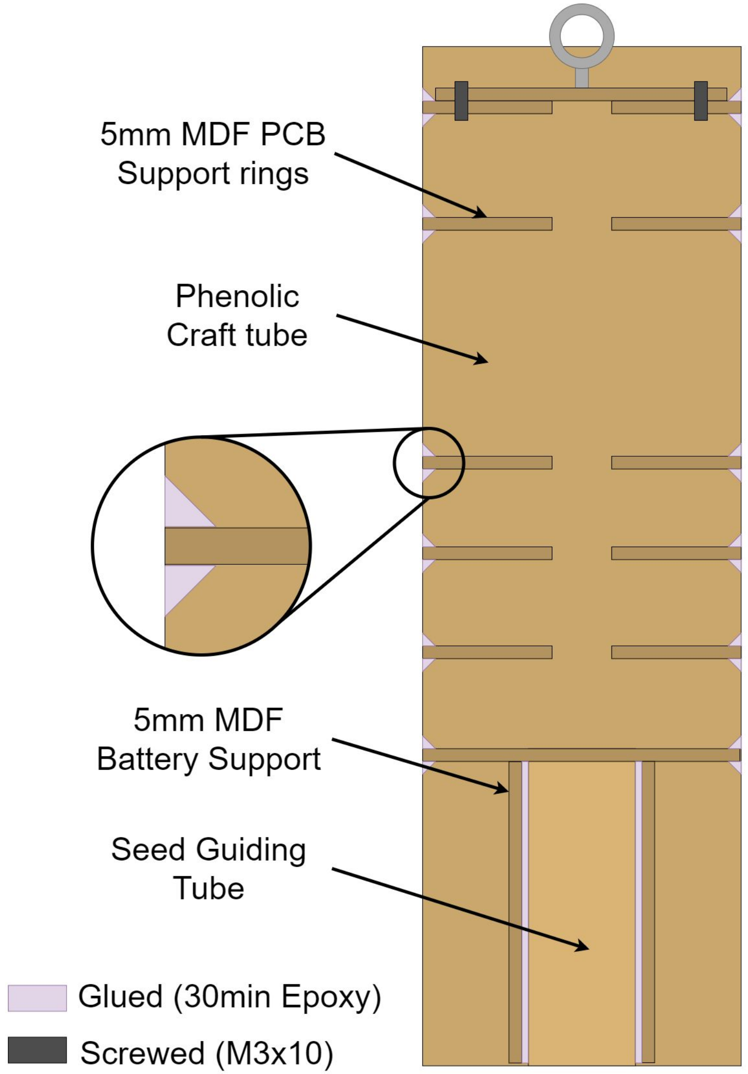


Concept Design : MapleCan



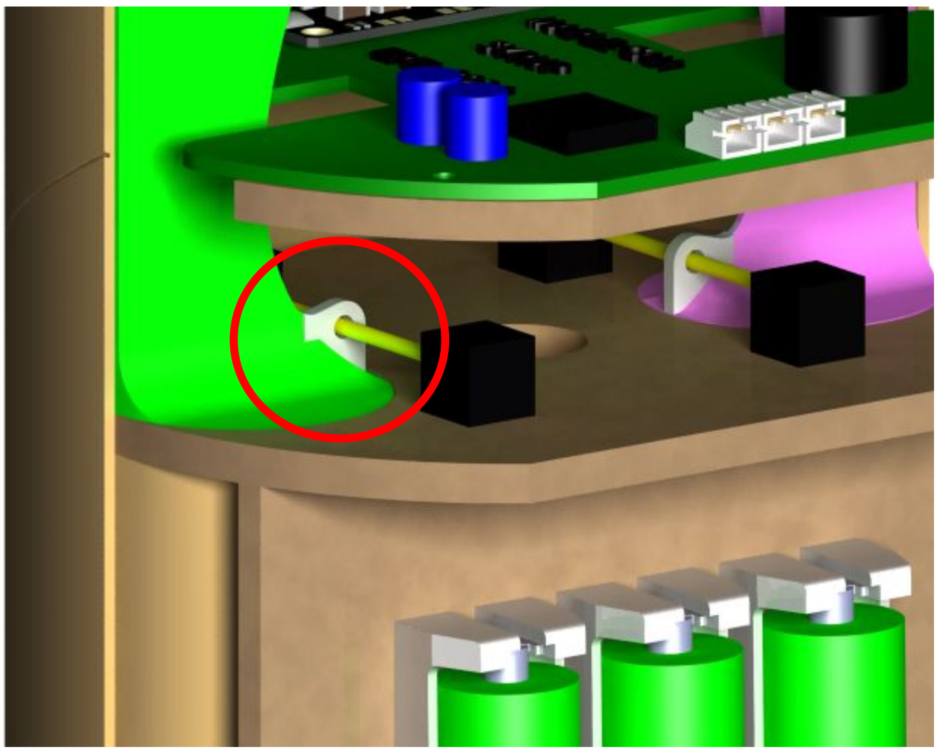
Mechanical Subsystem Overview

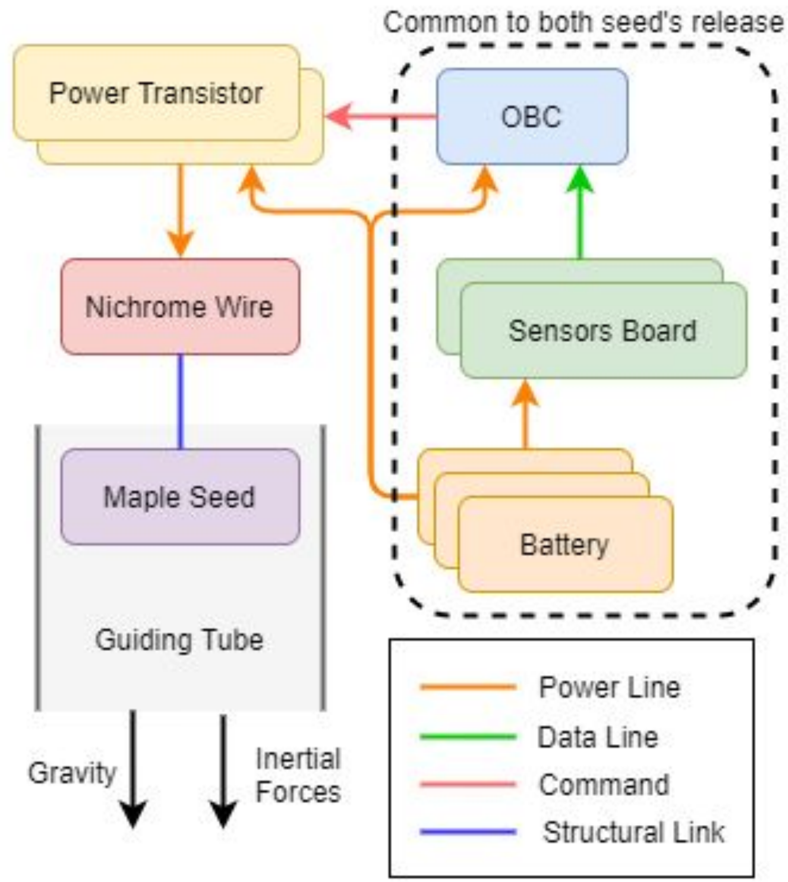
- PCBs are inserted from the top and screwed in the support rings
- Seeds and Batteries are integrated outside of the Can
- Whole lower assembly is then screwed in the bottom support ring



Payload Release Mechanism

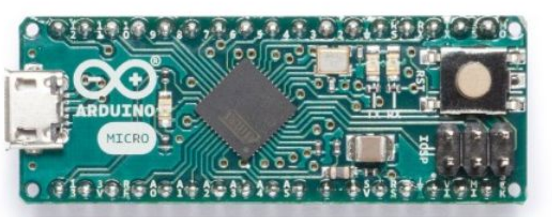
- **Nichrome wire burnt when ordered to by the OBC**
- **Gravity and inertial forces take care of the separation**

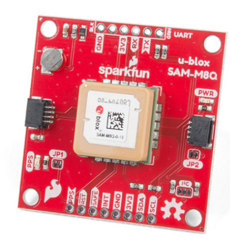




Avionics

- **On Board Computer**
  - Arduino - Micro : with internal homemade voltmeter circuit.
- **Barometer**
  - Absolute, thin-metal wall pressure sensor → best for vibrations
- **Memory**
  - Micro SD card and Arduino adapter → For internal data conservation and video recording.
- **GPS**
  - COTS “Sparkfun GPS” with integrated receiver, board and arduino compatibility
- **Switch**
  - “Microrupteur”, small button press, same as in payloads





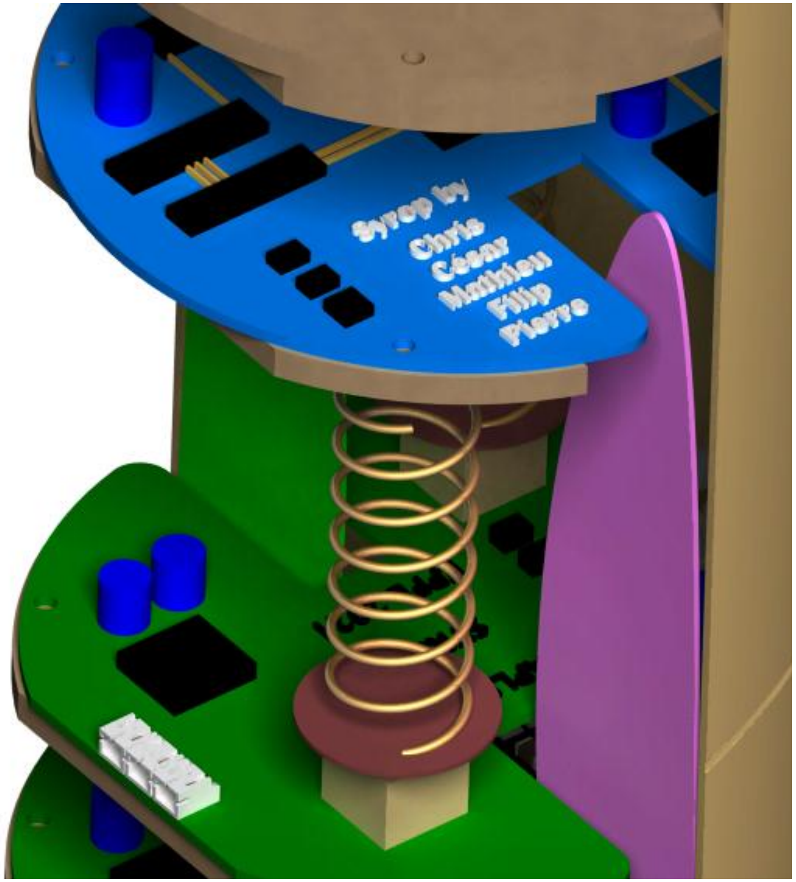
Telecommunication

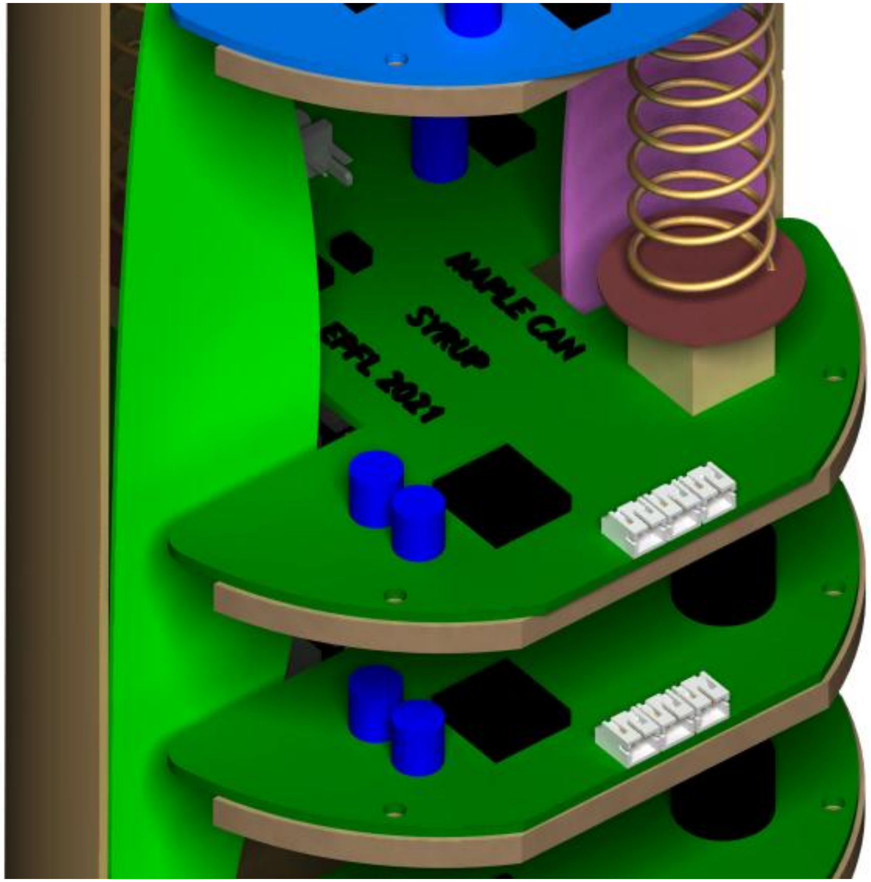
- **Telecommunication Board**
  - Digi Xbee 3 telecom board

- **Antennas**
  - Two Low Power Radio Solutions in the Can → redundancy and seeds on different sides

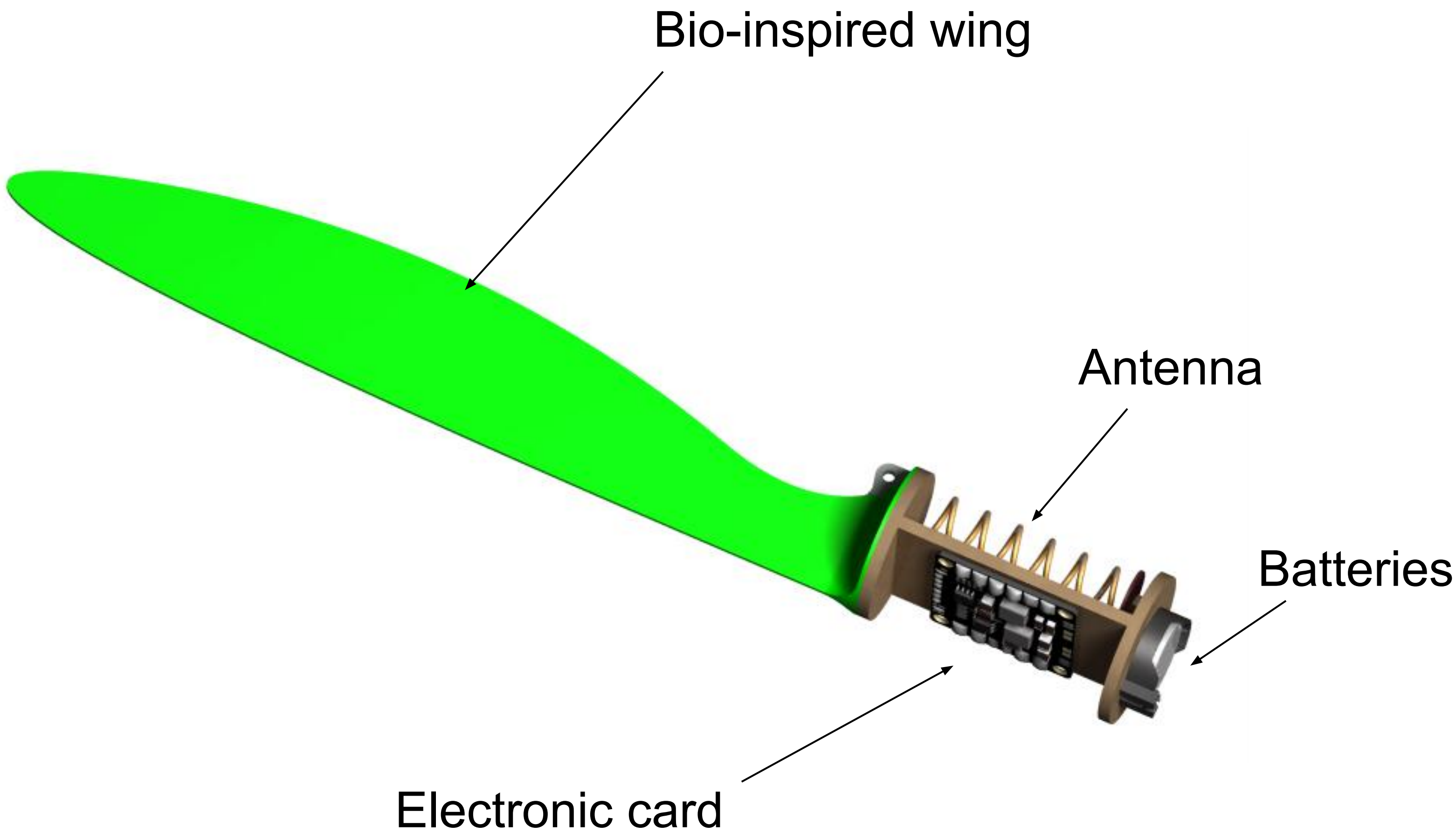
- **Ground Station**
  - Uses the same Xbee board and LPRS Private Mobile Radio to communicate with Can.

Concept Design : Zoom on PCBs

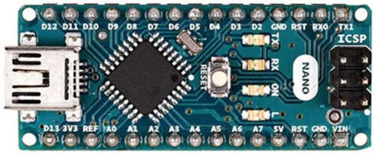




Concept Design : MapleSeed



Concept Design : MapleSeed



- **On Board Computer**
  - Arduino - Nano
  - Xbee 3 telecom board
  - Digi-Key 3 axis accelerometer IMU
- **Antenna**
  - Spiral Antenna and arduino compatible chip
- **Barometer**
  - Absolute, thin-metal wall pressure sensor → Best for vibrations
- **Thermometer**
  - Thermocoupler → Best resistance to vibrations

- **Switch**
  - “Microrupteur”, small button press, same as in MapleCan

Recovery

- **Parachute**
  - Fruity Chute CFC-12

- **Swivel**
  - To isolate parachute and can rotation → limit video rotation

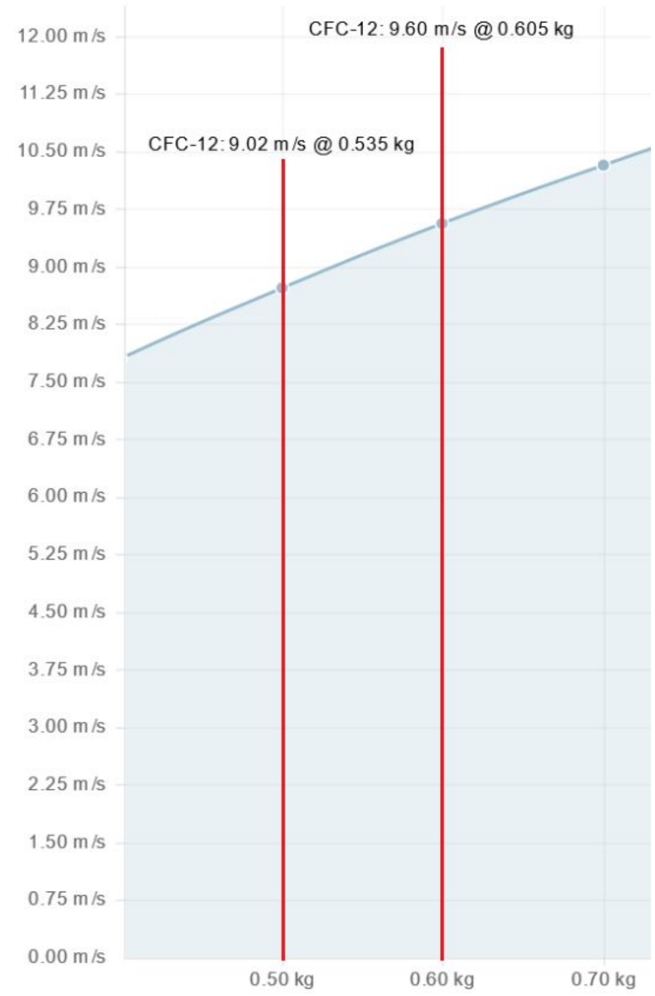
- **Camera**
  - 170° Wide angle lense
  - 1280x1024 pixels

- **Audio Beacon**
  - Piezo Buzzer Indicator with max 95dB

Descent Control Overview

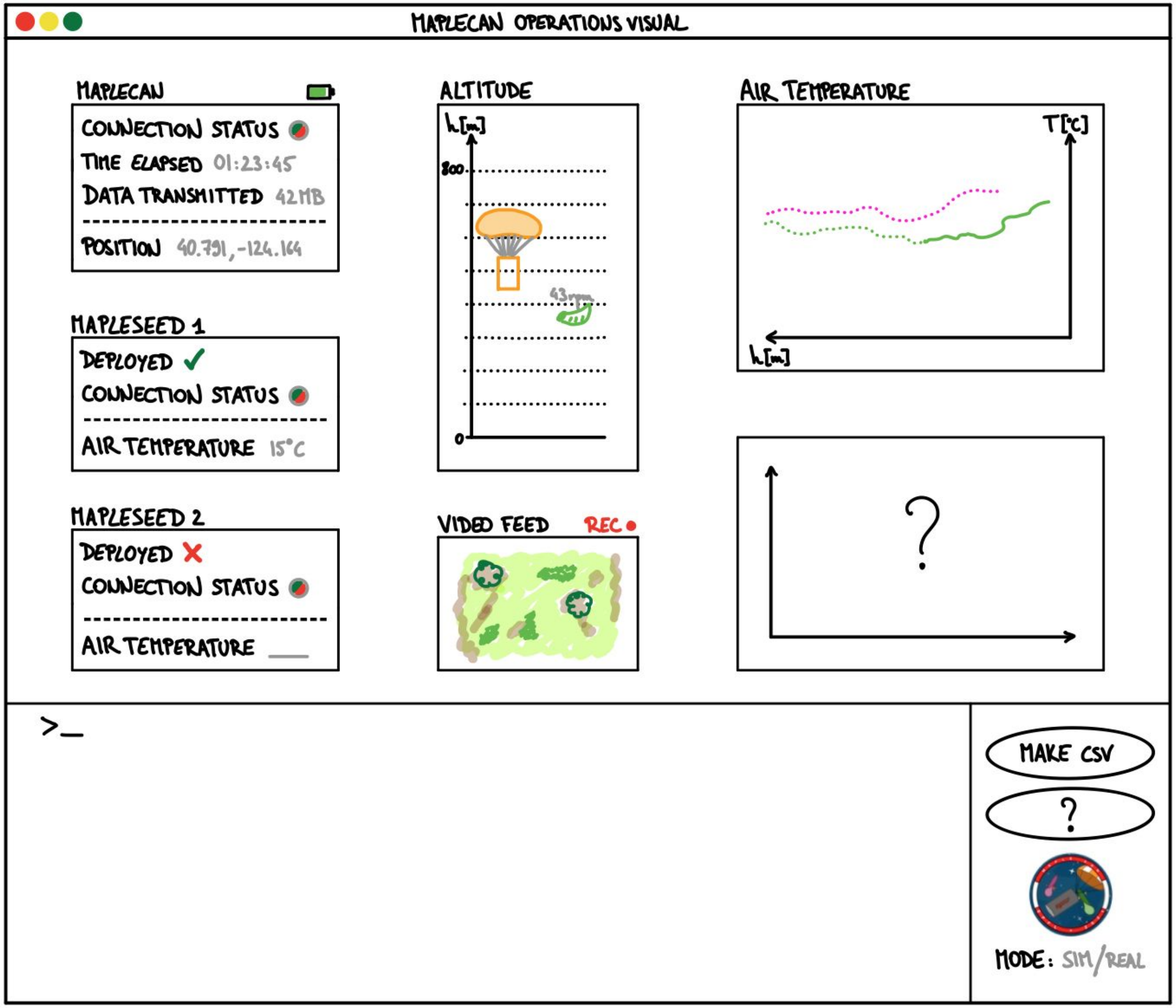
- **Container Descent Control:**
  → Fruity Chute CFC-12
  → 12” diameter & Cd of 1.50
  → 9.60[m/s] descent rate at 605[g]
  → 9.02[m/s] descent rate at 535[g]

- **Payload Descent Control:**
  → 15m/s max
  → Extensive test phase with 3D printed prototypes



Fruity Chutes Descent rate calculator

Ground Station User Interface



Budgets

- Preliminary Mass Budget
- Preliminary Container Energy Budget
- Preliminary Payload Energy Budget
- Preliminary Cost Budget

Mass Budget
Mass requirement of 600g

Component	Number	Mass [g]	Contingency [%]	Mass w. Contingency [g]
Structure (Phenolic+Supports)	1	302	10	332
CFC-12 parachute	1	37	20	44
Antenna	2	8	10	18
PCB	3	23	10	77
OBC	1	25	10	28
Seed	2	45	10	100
Camera	1	10	10	11
Screws & Glue	1	20	10	22
TOTAL				632 [g]
Contingency				10 %
TOTAL w. Contingency				695 [g]
				95 [g]

Container Energy Budget Autonomy of 2 hours required*

Component	Number	Energy [Wh]	Contingency [%]	Energy w. Contingency [Wh]
Arduino - Micro	1	0,7	10	0,77
Digi Xbee 3	1	1,58	10	1,74
LPRS PMR antenna	2	17	10	18,5
CPI-2207-95-SMT buzzer	1	1,8	10	1,9
Digi-Key BMP388 Barometer	1	0,58	10	0,64
Sparkfun GPS	1	0,825	10	0,908
TOTAL				24,46 [Wh]
Contingency				10 %
TOTAL w. Contingency				26,9 [Wh]
VTC6 18650, 3000m**Ah***3,6**V = 10,8 Wh** → 3 **batteries**				5,5 [Wh]

** Buzzer needs an autonomy of 10h*

Payload Energy Budget
Autonomy of 2 hours required

Component	Number	Energy [Wh]	Contingency [%]	Energy w. Contingency [Wh]
Arduino - Nano	1	0,4	10	0,44
Xbee 3	1	0,16	10	0,18
RS PRO - thermometer	1	-	-	-
BMP388 - barometer	1	-	-	-
LoRa1278 - RF Antenna	1	0,9	10	1
Digi-Key 1041-ND IMU	1	-	-	-
TOTAL				1,62 [Wh]
Contingency				20 %
TOTAL w. Contingency				1,95 [Wh]
CR3032, 500mAh*3V = 1,5 Wh → 2 batteries				**1,05 [Wh]**

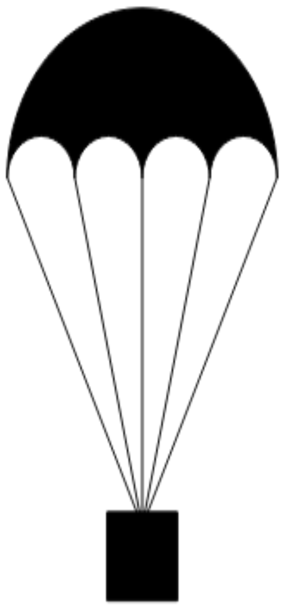
Cost Budget
Cost requirement of max 865 CHF

Component	Number	Cost [CHF]	Contingency* [%]	Cost w. Contingency [CHF]
CFC-12 parachute	1	50	50	75
MapleCan Electronics	1	150	50	225
MapleSeed Electronics	2	70	50	210
MapleCan Materials	1	50	50	75
MapleSeed Materials	2	4	50	12

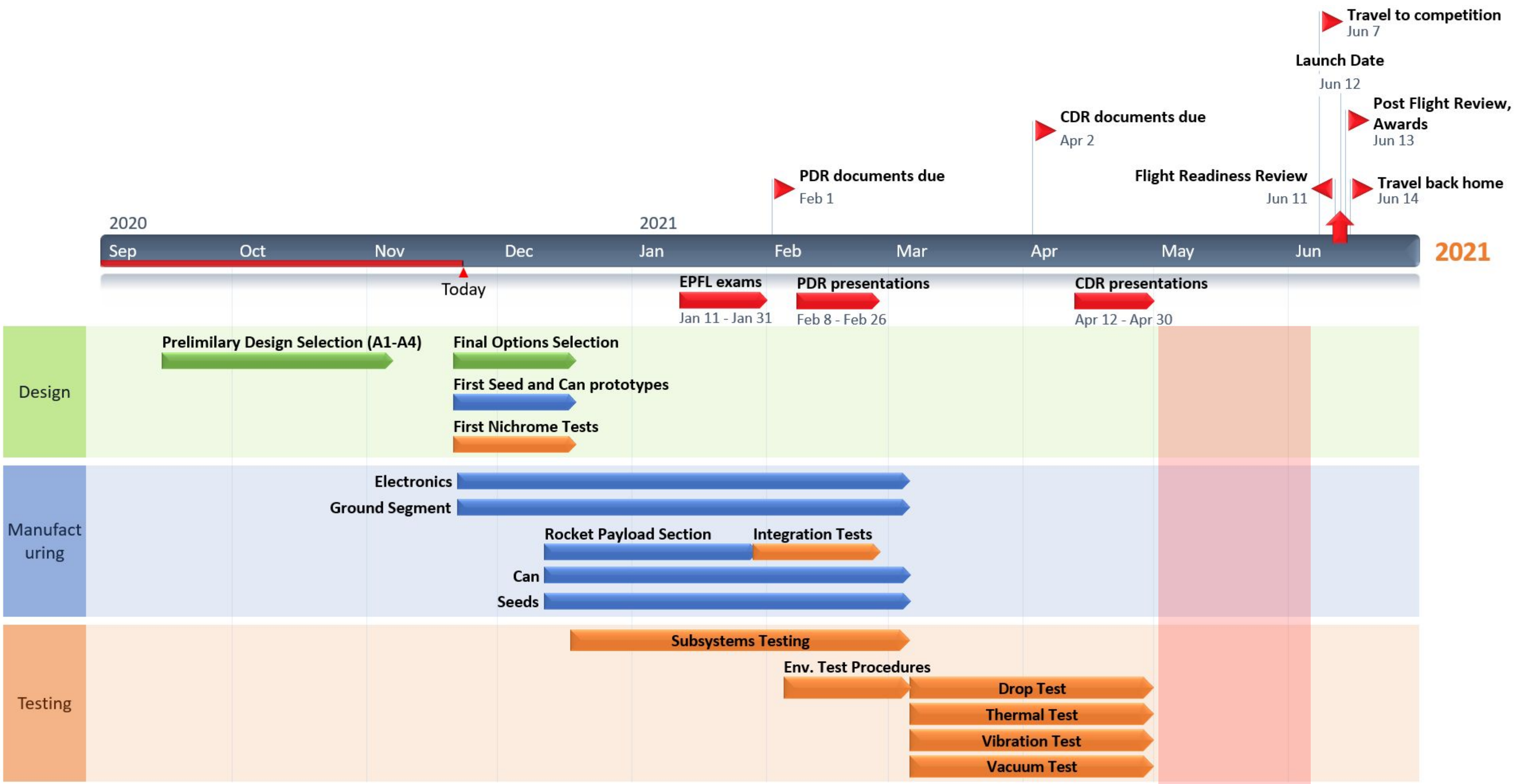
TOTAL	597 [CHF]
Contingency	10 %
TOTAL w. Contingency	657 [CHF]
***shipping fees unknown**	**208 [CHF]**

CanSat Integration and Test Planning

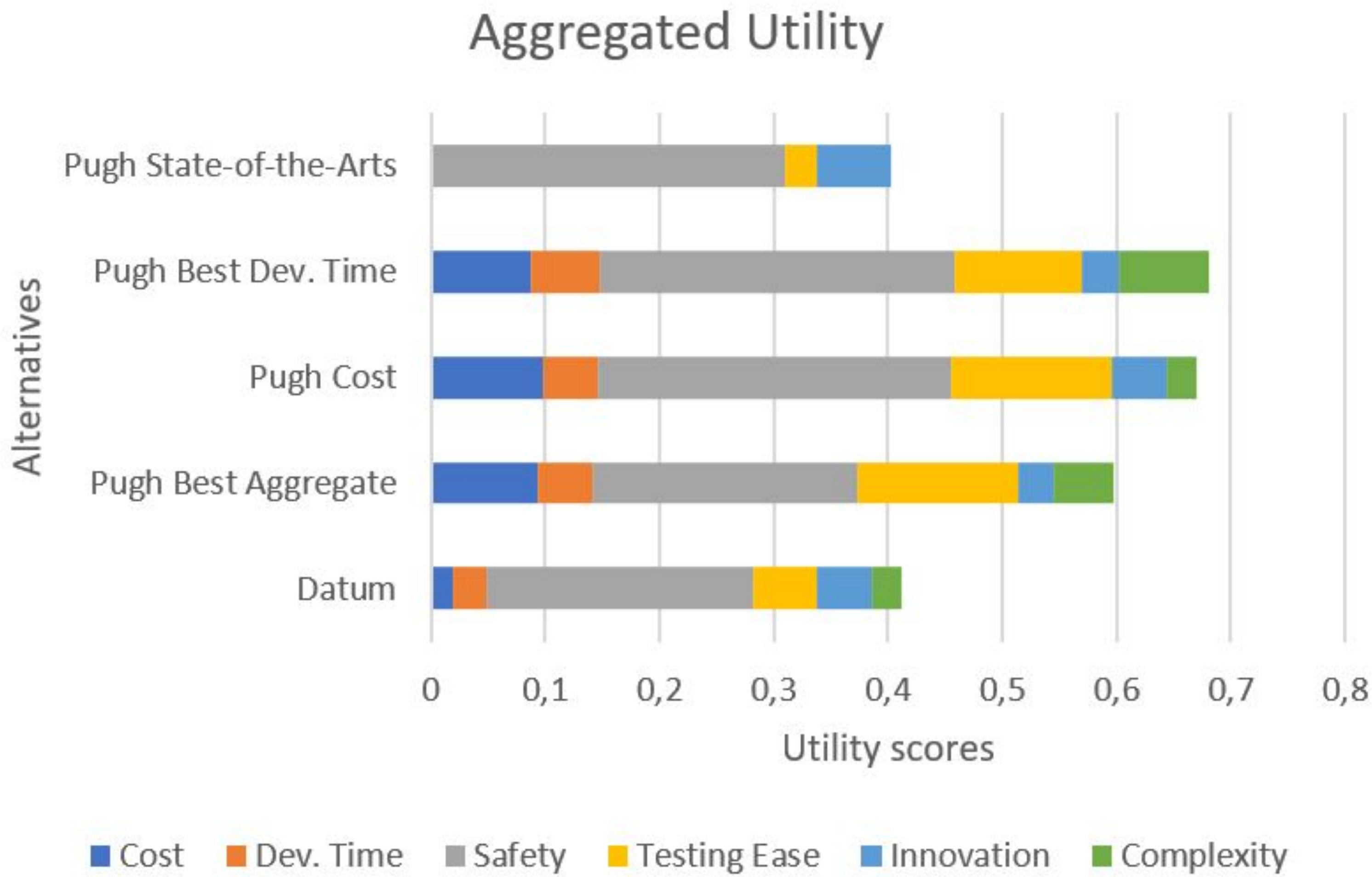
- Schedule
- Tests planning



Program Schedule and Tests Overview



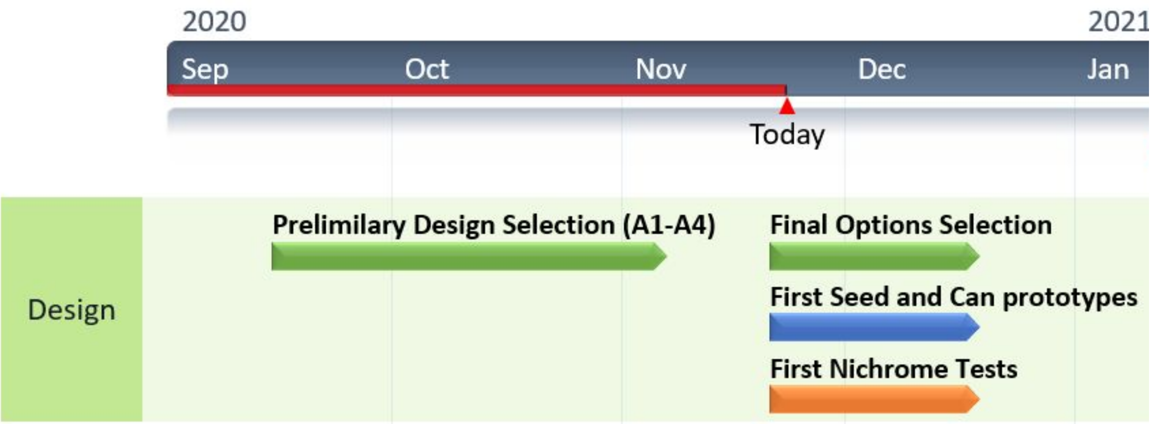
Multi-Attributes Utility Analysis Results



CanSat Design Selection Tests

Tests/Investigations needed to select the last alternatives :

- Can material (3D printed polymer vs phenolic)
- Seed material (Polystyrene vs 3D printed polymer)
- Seed power supply (Solar vs Battery)

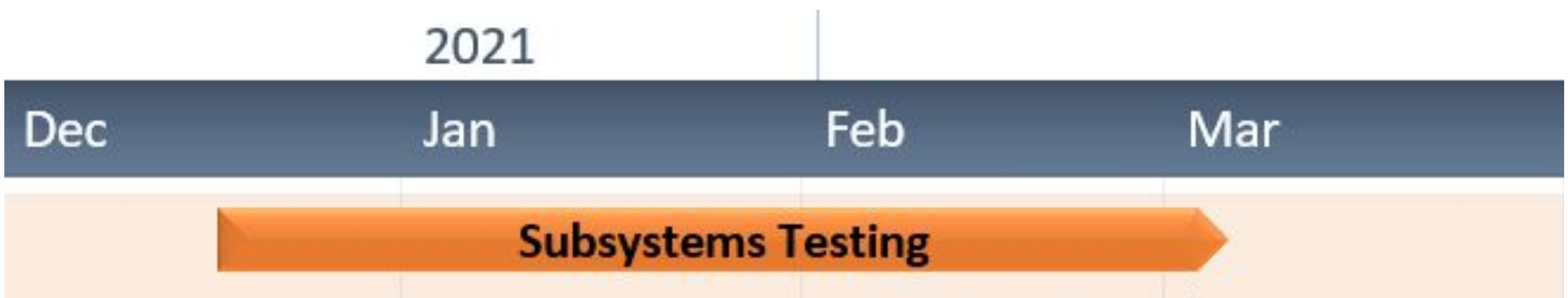


- First Nichrome tests as proof of concept for release mechanism

Subsystem Level Testing Plan

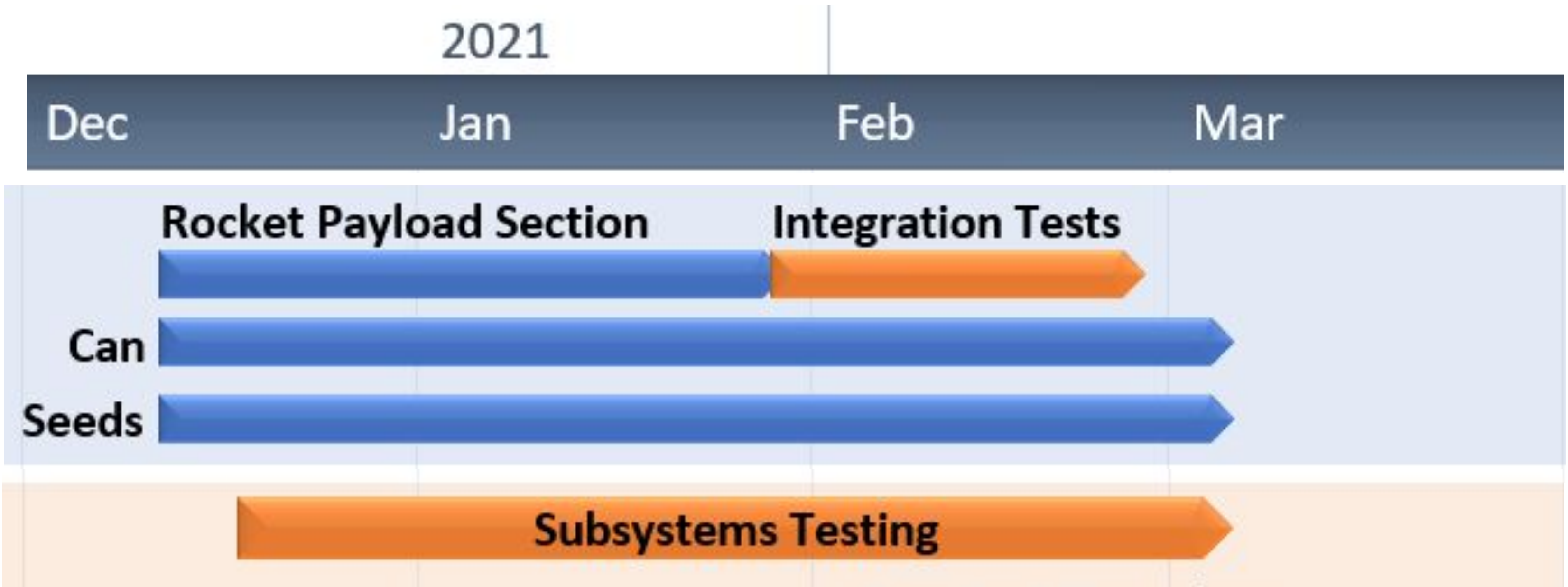
Tests for different components and interfaces

- Sensors (measurements in lab conditions)
- CDH (measurements in lab conditions)
- EPS (autonomy)
- FSW (simulations to test software behavior)



Test after manufacturing of main components

- Integration (fit) tests using a mock PL section



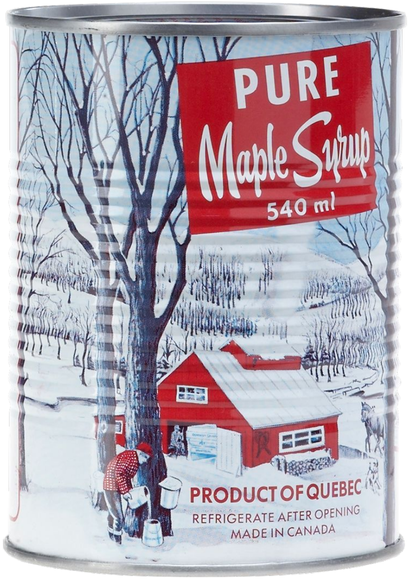
- Release Mechanism activation (on ground)
- Telemetry communication
- Descent rate → drop test from Sauvabelin tower (35m)

Environmental Test Plan

- **Drop test** (30G) to make sure release mechanism holds the parachute opening shock
- **Thermal test** (60C for a period of 2 hours in a thermal chamber)
- **Vibrations tests** (0 Hz to 233 Hz using an orbit sander, generating about 20 to 29 Gs)
- **Vacuum Test** (simulates the drop in pressure during the flight using a vacuum cleaner)

Conclusions

- **Design phase in progress**
- **Fulfilled the team charter objectives**
  - Team work, communication
  - ENG-421 course theories
  - Strong work ethics
  - Core value : simply have fun



- **Applied some learned concepts to our respective interdisciplinary projects (Rocket Team, Spacecraft Team)**

Questions Time !

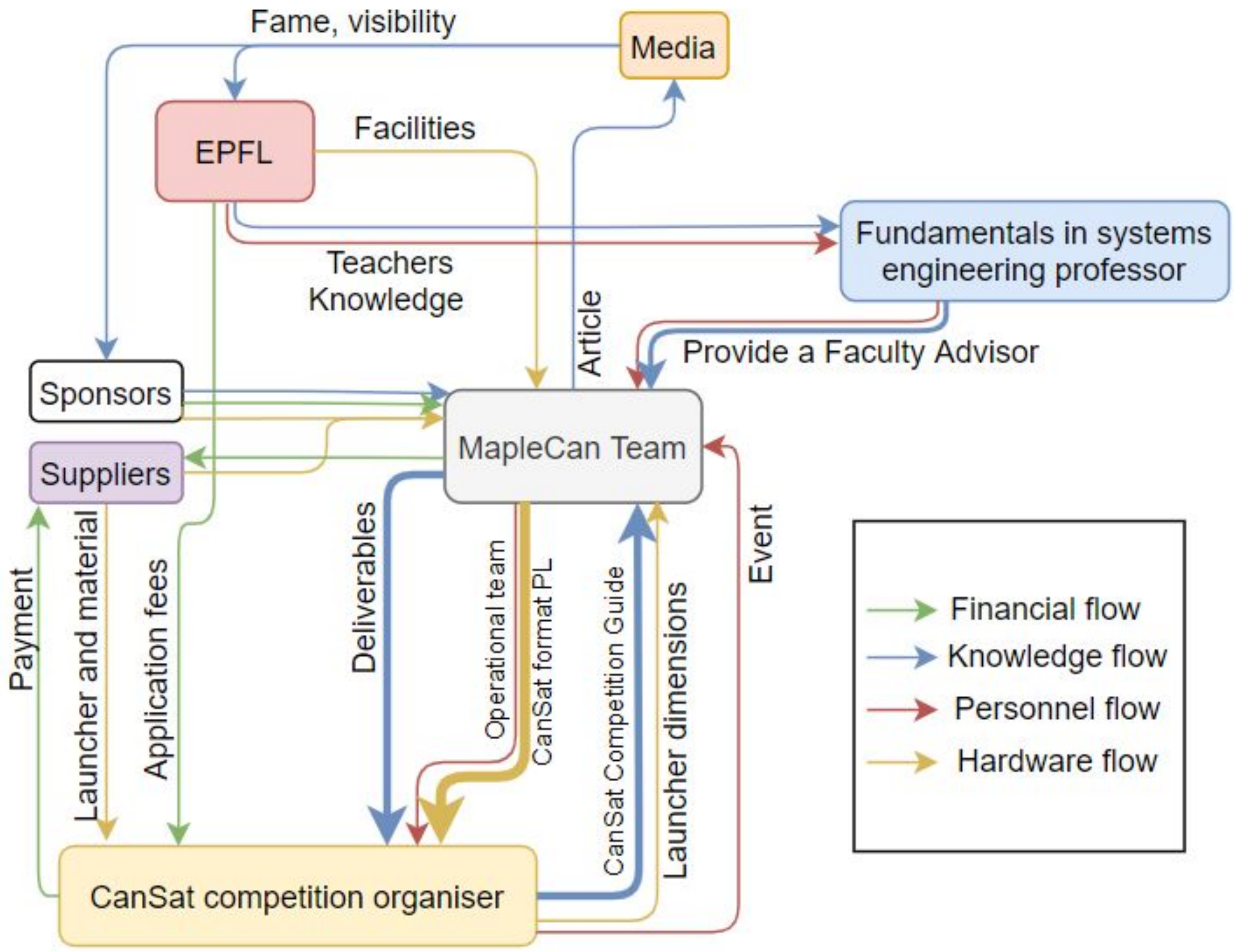
PDR Technical Data Package

- **Acronyms**
- **Stakeholders Analysis**
- **Driver requirements**
- **Mind map**
- **OPD & OPL**
- **Pugh matrices**
- **Multi-Attributes Utility Analysis**
- **Risk Analysis**

Acronyms

AV	Avionics	**MA**	Master Degree
CAD	Computer Aided Design	**MC**	MapleCan
CDH	Commands and Data Handling	**MT**	Micro Engineering
COM	TeleCommunication	**PCBs**	Printed Circuit Boards
CSC	CanSat Competition	**PDR**	Preliminary Design Review
EPS	Electric Power Supply	**PL**	Payload
FSW	Flight SoftWare	**PRM**	Payload Release Mechanism
GM	Mechanical Engineering	**RE**	Recovery
GS	Ground Segment	**SE**	System Engineering
GSW	Ground Station SoftWare	**VID**	Video Camera
CSCG	CanSat Competition Guide		

Stakeholders Analysis
Value network



Driver Requirements 1/2

Mission Objectives

- The container shall include a pressure sensor to measure altitude +/- 3 meters.
- The container shall include a GPS sensor to track its position.
- The science payload shall measure altitude +/- 3 meters.
- The science payload shall measure air temperature +/- 1 degrees celsius.

Performance

- The container parachute shall open immediately when deployed from the rocket.
- The descent rate of the cansat shall be 12 meters/second +/- 5m/s.
- The science payload shall descend spinning passively like a maple seed with no propulsion.
- The science payload shall have a descent rate comprised between 18 and 20 m/s.

Structural Constraints

- The container shall be solid and fully enclose the science payloads.
- The cansat shall weight no more than 570 grams.
- The cansat shall fit in a cylindrical envelope of 125 mm diameter x 400 mm length.

Energy

- The cansat shall operate for a minimum of 2h when integrated into the rocket.

Driver Requirements 2/2

Telemetry

- The ground station shall command the cansat to start transmitting telemetry prior to launch.
- The science payloads shall start transmitting telemetry after commanded to do so by the container.
- The science payload telemetry shall be transmitted to the container only.
- The container shall transmit its telemetry and the payload telemetry received once per second in the format described in the CSCG Section 3.3.

Environment

- The cansat must operate during the environmental tests laid out in Section 3.5 of the CSCG.

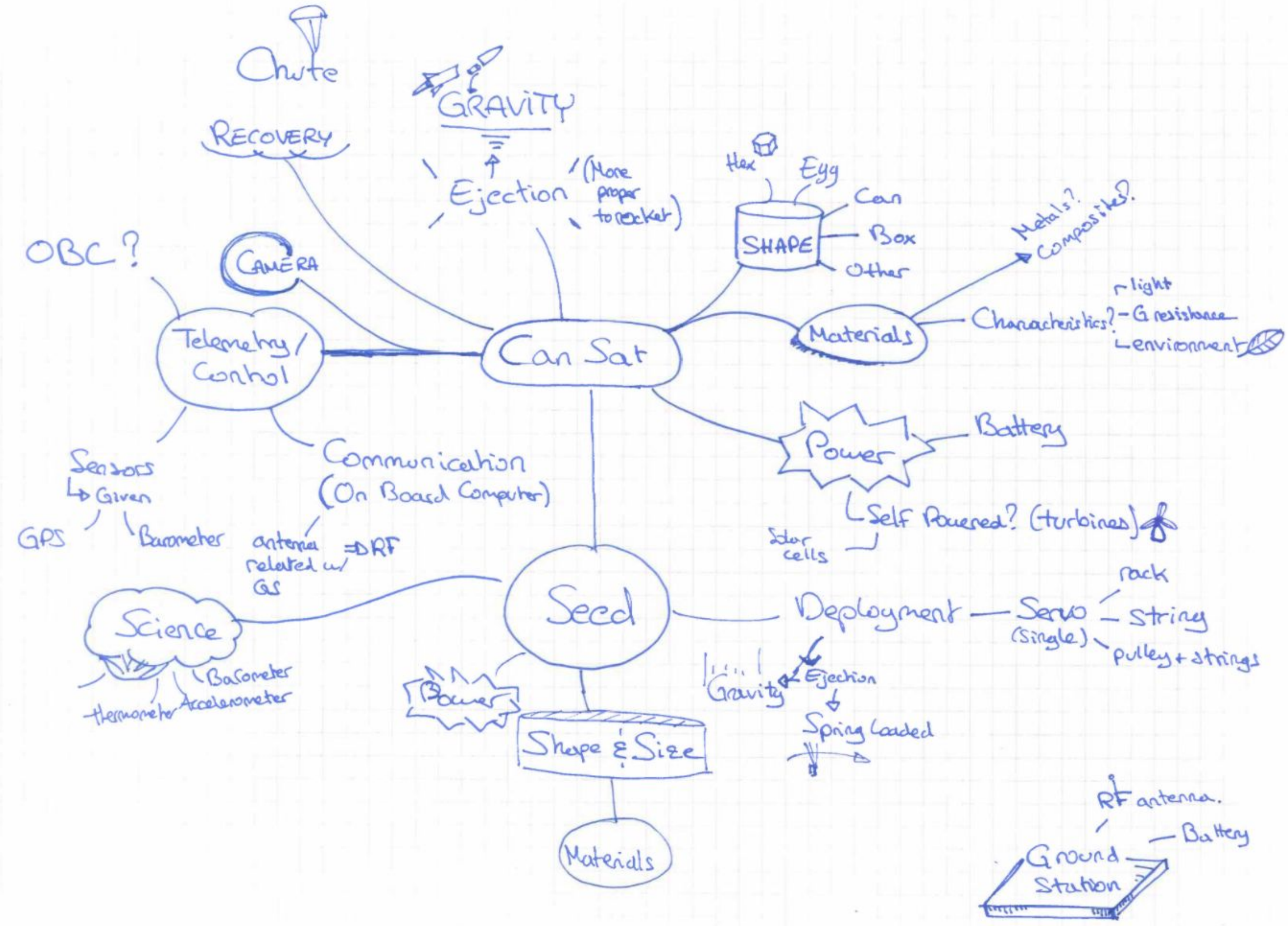
Recovery

- The container shall include an audio beacon.
- The container shall be colored fluorescent orange.
- The wing of the science payload shall be colored fluorescent, one in pink and the other one in green.

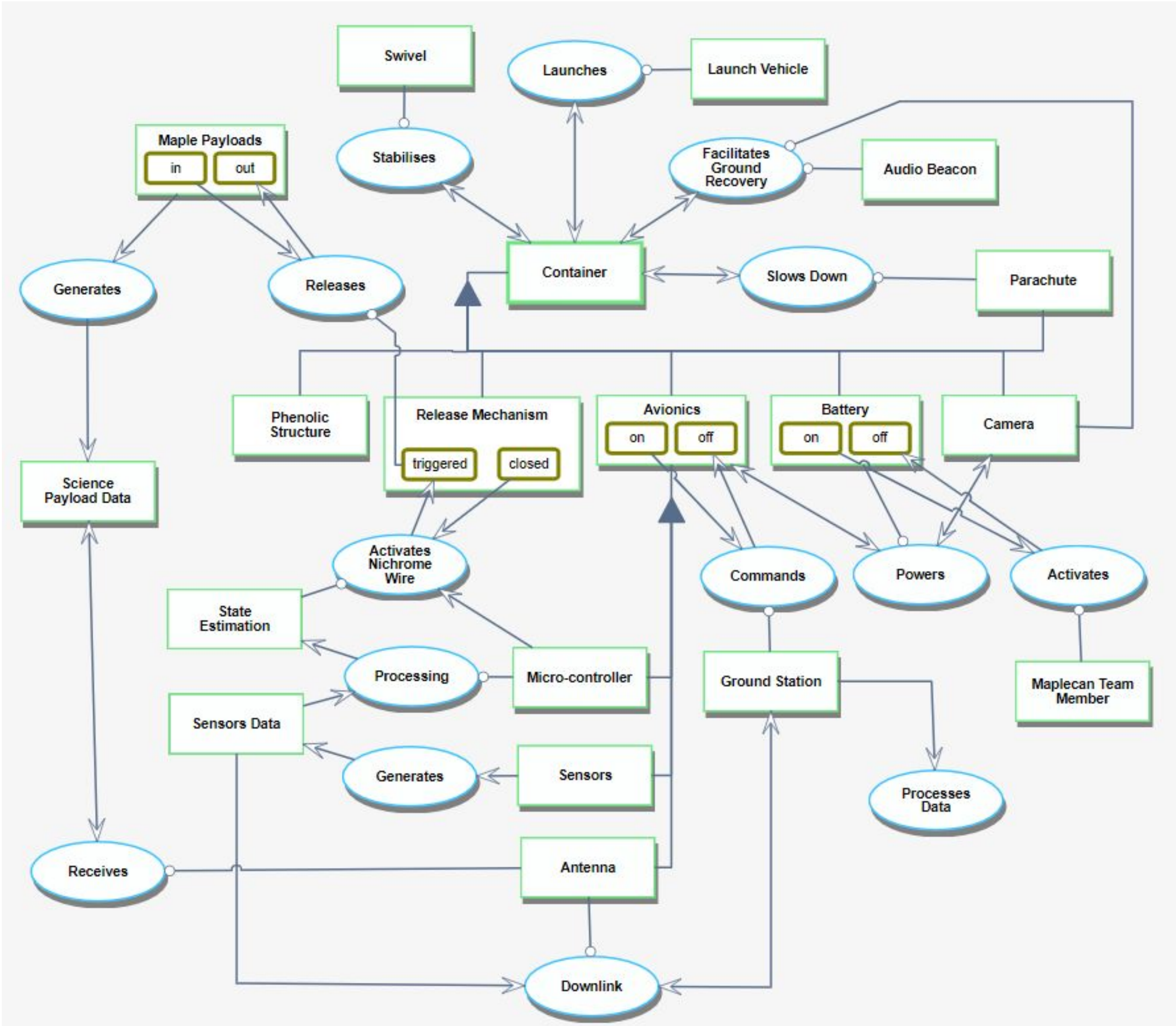
Ground Station

- All telemetry shall be displayed in real time during descent on the ground station.

Concept Generation Mind Map



OPD MapleCan



OPL MapleCan 1/2

Release Mechanism can be triggered or closed.

Avionics can be on or off.

Battery can be on or off.

Maple Payloads can be in or out.

Sensors Data is informatical.

Container consists of Avionics, Battery, Camera, Parachute, Phenolic Structure, and Release Mechanism.

Avionics consists of Antenna, Micro-controller, and Sensors.

State Estimation is informatical.

Powers requires Battery.

Powers affects Avionics and Camera.

Releases changes Maple Payloads from in to out.

Releases requires Release Mechanism at state triggered.

Generates consumes Sensors.

Generates yields Sensors Data.

Processing requires Micro-controller.

Processing consumes Sensors Data.

Processing yields State Estimation.

Activates Nichrome Wire changes Release Mechanism from closed to triggered.

Activates Nichrome Wire requires State Estimation.

Activates Nichrome Wire consumes Micro-controller.

OPL MapleCan 2/2

Slows Down requires Parachute.

Slows Down affects Container.

Launches requires Launch Vehicle.

Launches affects Container.

Activates changes Battery from on to off.

Activates requires Maplecan Team Member.

Commands changes Avionics from on to off.

Commands requires Ground Station.

Stabilises requires Swivel.

Stabilises affects Container.

Facilitates Ground Recovery requires Audio Beacon and Camera.

Facilitates Ground Recovery affects Container.

Receives requires Antenna.

Receives affects Science Payload Data.

Generates consumes Maple Payloads.

Generates yields Science Payload Data.

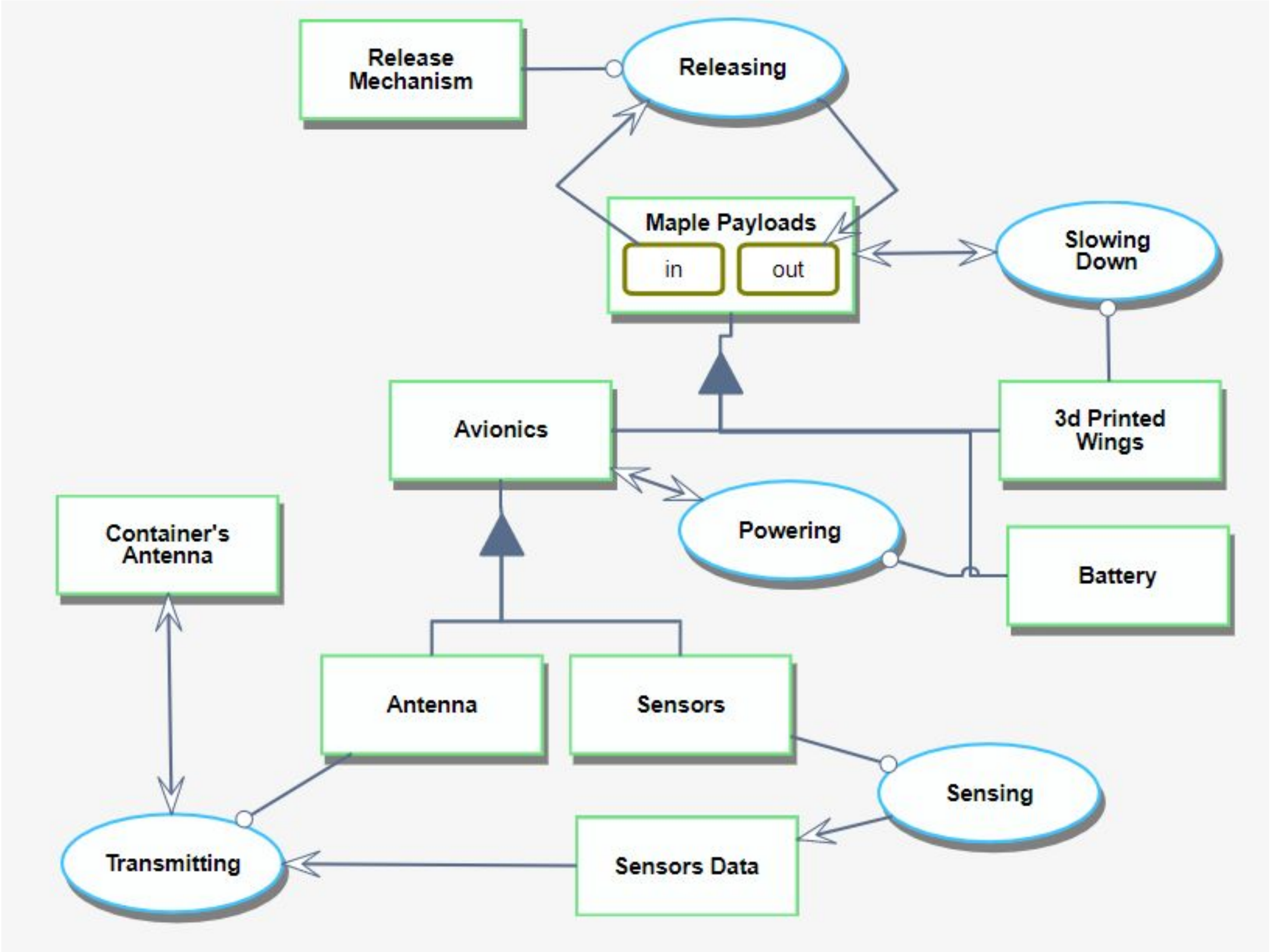
Downlink requires Antenna.

Downlink affects Ground Station.

Downlink consumes Sensors Data.

Processes Data consumes Ground Station.

OPD Seed PL


Release Mechanism
Releasing
Maple Payloads
in
out
Slowing Down
Avionics
3d Printed Wings
Container's Antenna
Powering
Battery
Antenna
Sensors
Sensing
Transmitting
Sensors Data

OPL Seed PL

Maple Payloads can be in or out.

Maple Payloads consists of 3d Printed Wings, Avionics, and Battery.

Avionics consists of Antenna and Sensors.

Sensors Data is informatical.

Releasing changes Maple Payloads from in to out.

Releasing requires Release Mechanism.

Slowing Down requires 3d Printed Wings.

Slowing Down affects Maple Payloads.

Powering requires Battery.

Powering affects Avionics.

Sensing requires Sensors.

Sensing yields Sensors Data.

Transmitting requires Antenna.

Transmitting affects Container's Antenna.

Transmitting consumes Sensors Data.

Subsystem Level Selections 1/8

Eight **Pugh matrices** done to compare subsystems' alternatives and generate system concept architectures

Criteria/alternatives	1	2	3
Seed Deployment	Servo + rack	Servo + string	Nichrome Wire
Cost	-	-	Datum
Mass	-	-	Datum
Development Time	-	-	Datum
Development Simplicity	0	0	Datum
Reliability	0	-	Datum
Testing Ease	+	0	Datum
Sum	-2	-4	Datum

Table 1: Pugh Matrix: Seed Deployment.

Subsystem Level Selections 2/8

Criteria/alternatives	1	2	3	4	5	6
MapleCan Spin stabilization	Fins + CM position	Inertial wheel	Fans (drone propellers)	Cold gas Thrusters	Simple swivel	Software stabilization
Cost	+	Datum	+	-	+	-
Development Time	+	Datum	-	-	+	-
Mass	+	Datum	0	0	+	+
Complexity	0	Datum	-	-	+	-
Volume	0	Datum	0	-	+	+
Correction Range	-	Datum	+	+	-	0
Sum	+2	Datum	0	-3	+4	-1

Table 2: Pugh Matrix: MapleCan Spin stabilization.

Subsystem Level Selections 3/8

Criteria/alternatives	1	2	3	4	5	6
MapleCan Materials	Sheet Metal	Composites	Polymers (bulk)	Phenolic Kraft	Wood and aero covers	Polymers (3D printed)
Cost	-	-	-	Datum	0	+
Mass	-	0	0	Datum	-	+
Young modulus	+	+	-	Datum	-	-
Resilience	+	+	+	Datum	-	-
Manufacturing Ease	-	-	0	Datum	0	+
Sum	-1	0	-1	Datum	-3	+1

Table 3: Pugh Matrix: MapleCan Materials.

Subsystem Level Selections 4/8

Criteria/alternatives	1	2	3	4
MapleCan Power	Wind Turbine	Battery	Radioisotope Thermoelectric Generator	Solar cells
Cost	0	Datum	-	0
Mass	-	Datum	-	-
Volume	-	Datum	-	-
Development Time	-	Datum	-	-
Capacity	-	Datum	+	-
Sum	-4	Datum	-3	-4

Table 4: Pugh Matrix: MapleCan Power.

Subsystem Level Selections 5/8

Criteria/alternatives	1	2	3
Descent speed control	Parachute	"Helicopter" blades	Propulsive Braking
Cost	Datum	0	-
Mass	Datum	-	-
Development Time	Datum	-	-
Reliability	Datum	0	+
Energy need	Datum	-	-
Testing time	Datum	0	-
Complexity	Datum	-	-
Sum	Datum	-4	-5

Table 5: Pugh Matrix: MapleCan Descent speed control.

Subsystem Level Selections 6/8

Criteria/alternatives	1	2	3	4
MapleCan Ground Recovery	Smoke Generator	Audio Beacon	Helium Balloon Inflator	K-9 and drugs
Cost	-	Datum	-	-
Complexity	-	Datum	-	-
Feasability	-	Datum	-	-
Effectiveness	+	Datum	+	+
Energy need	-	Datum	-	+
Sum	-3	Datum	-3	-1

Table 6: Pugh Matrix: MapleCan Ground Recovery.

Subsystem Level Selections 7/8

Criteria/alternatives	1	2	3	4	5
Seed Material	Molded Polymer	Sheet Metal	Polystyrene	Composites (foam core)	Polymer (3D printed)
Cost	-	-	+	Datum	+
Mass	-	-	+	Datum	0
Young Modulus	-	0	-	Datum	-
Resilience	+	+	-	Datum	-
Manufacturing Ease	-	0	+	Datum	+
Sum	-3	-1	+1	Datum	0

Table 7: Pugh Matrix: Seed Material.

Subsystem Level Selections 8/8

Criteria/alternatives	1	2	3	4
Seed Power	Solar	Battery	Capacitor	Dynamo
Cost	+	-	Datum	+
Mass	-	-	Datum	-
Volume	-	0	Datum	-
Development Time	-	+	Datum	-
Capacity	0	+	Datum	0
Sum	-2	0	Datum	-2

Table 8: Pugh Matrix: Seed power.

Alternatives

Generated thanks to Pugh matrices, by focusing on one attribute at a time (e.i. best in terms of cost or development time)

		Seed Deployment	Spin stabilization	Materials	Power	Descent control	Ground RE	Seed Material	Seed Power
1	Datum	Nichrome Wire	Inertial wheel	Phenolic	Battery	Parachute	Audio Beacon	Composites (foam core)	Capacitor
2	Pugh best aggregate (the one with the most +)	Nichrome Wire	Simple Swivel	Polymers (3D printed)	Battery	Parachute	Audio Beacon	Polystyrene	Capacitor
3	Pugh cost	Nichrome Wire	Simple Swivel	Polymers (3D printed)	Battery	Parachute	Audio Beacon	Polystyrene	Solar
4	Pugh dev time	Nichrome Wire	Simple Swivel	Phenolic	Battery	Parachute	Audio Beacon	Polymer (3D printed)	Battery
5	Pugh state-of-the-Art (unlimited time and money)	Servo + Rack	Cold gas Thrusters	Composites	RTG	Propulsive Braking	Helium Balloon Inflator	Molded Polymer	Solar

Multi-Attributes Utility Analysis 2/5
Weighted Attributes Averaging Matrix

Weighting of Evaluation Criteria

Only change numbers above diagonal line

Markings:
+ 3 = Y is much more important than X
+ 2 = Y is more important than X
+ 1 = Y is slightly more important than X
+ 0 = Y is as important as than X / Not Applicable
- 1 = Y is slightly less important than X
- 2 = Y is less important than X
-3 = Y is much less important than X

	Cost (SIB)	dev time(SIB)	mission safety (LIB)	testing ease (LIB)	innovation (LIB)	complexity (SIB)		SUM	
Cost (SIB)		1	2,5	-0,25	-1,5	-1,5	0	0,25	
dev time(SIB)			2,25	-0,5	-1	-0,5	0	0,25	
mission safety (LIB)				-2,25	-3	-2,75	0	-8	
testing ease (LIB)					-1	0,25	0	-0,75	
innovation (LIB)						1,5	0	1,5	
complexity (SIB)							0	0	
								0	
SUM LINE	**0**	**1**	**4,75**	**-3**	**-6,5**	**-3**	**0**		
RANK	**3**	**2**	**1**	**4**	**6**	**5**			
Adjusted Importance in %	16%	18%	31%	14%	8%	13%	0%	∑ =	100%

Multi-Attributes Utility Analysis 3/5

Weighted Attributes*

Attribute	Cost	Dev. Time	Mission safety	Testing Ease	Innovation	Complexity
Weights k_i [%]	16	18	31	14	8	13
Rank	3	2	1	4	6	5

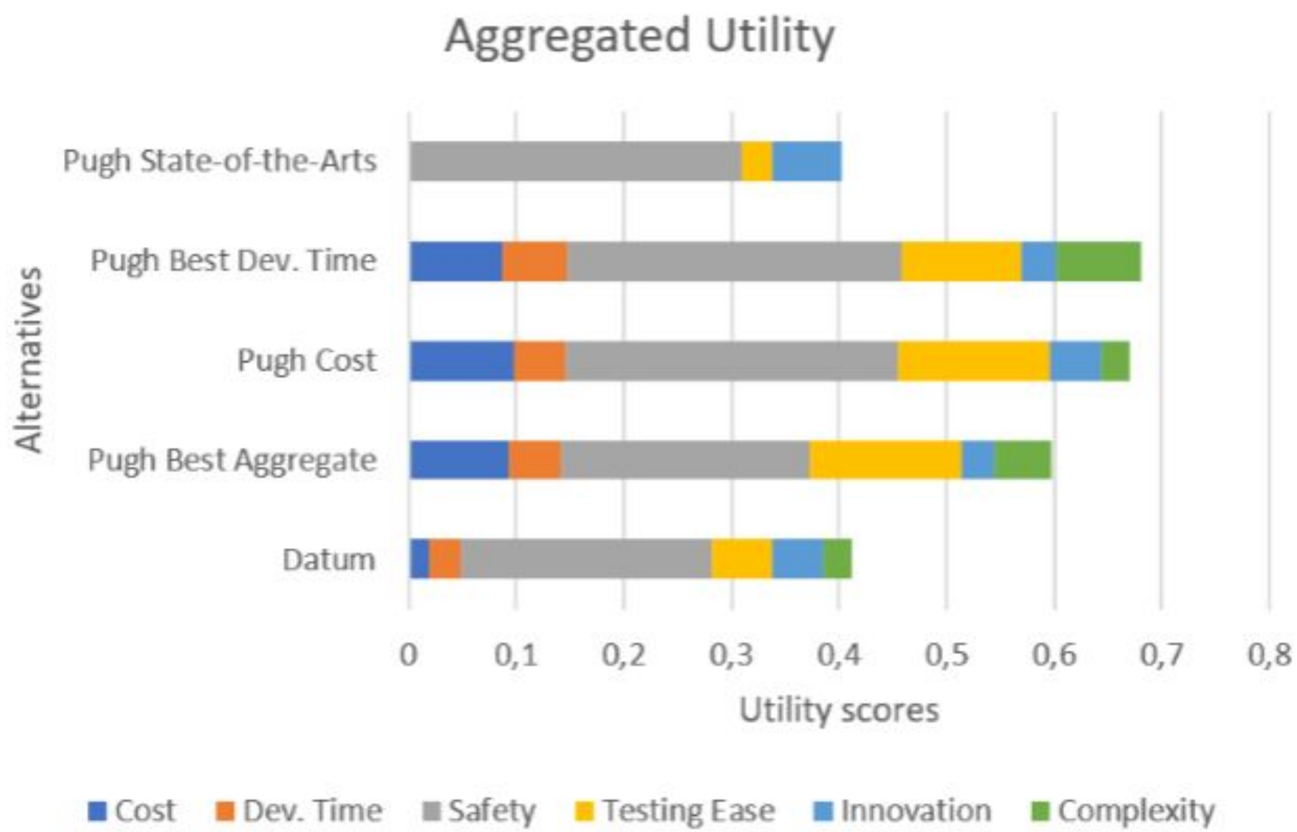
Scoring scales for attributes with arbitrary units

mission safety	testing ease	innovation	complexity
	5 : very easy	5 : very innovative	5 : very complex
4 : 99-100 %	4 : easy	4 : innovative	4 : complex
3 : 90-99 %	3 : no problem	3 : recent tech	3 : no problem
2 : 60-90 %	2 : challenging	2 : old tech	2 : simple
1 : 0-60 %	1 : very challenging	1 : very old tech	1 : very simple

Scoring of the Alternatives

	Cost	dev time	mission safety	testing ease	innovation	complexity
	$	weeks	a.	a.	a.	a.
	SIB	SIB	LIB	LIB	LIB	SIB
Datum	880	25	3	2	3	4
Pugh best aggregate (the one with the most +)	420	22	3	5	2	3
Pugh cost	390	22	4	5	3	4
Pugh dev time	450	20	4	4	2	2
Pugh state-of-the-Art (unlimited time and money)	1,00E+09	500	4	1	4	5

Multi-Attribute Utility Analysis 5/5
Aggregate Utility Function



Mission Risk analysis 1/3

Risk	Probability %	Consequence max 100	Severity max 100	Mitigation
Readiness for competition	5.00	100	5	Intermediate evaluation milestones set MapleSat to success, make sure to pass them in time.
Funding problem	1.00	100	1	MapleSat cost is limited to $1000 by requirement. Start saving for the flight tickets.
Materials will fail	2.00	85	1.7	Frequently check for failures and take a 10-15% margin on requirements.
Structure will collapse on take off	8.00	90	7.2	Extensive testing/simulations.
Electronics will short circuit etc.	8.00	90	7.2	Encapsulate the box, plan for redundancy.
Sensors might not work	8.00	90	7.2	Buy reliable components and test for failures.
MapleSat will run out of power	2.00	100	2	Charge batteries before tests and launch, have a battery voltage sensor and a lower consumption mode?
Environmental issues (humidity, temperature etc.)	2.00	70	1.4	Cover all aspects/combos during planning/testing. Worst case scenario, MapleSat has a short flight anyway and launch will be aborted if conditions aren't good. Seal the can.

Mission Risk analysis 2/3

MapleSat will get stuck in rocket	1.00	100	1	Avoid having anything sticky near the MapleSat when possible. Choose low friction/undeformable materials.
MapleCan parachute problem	2.00	100	2	Make a lot of experiments.
MapleCan won't fulfill in-flight requirements e.g. descent rate, video stabilization etc.	8.00	40	3.2	We will be penalized but mission data might still be good. Take some 10-15% margin on requirements. Apply software corrections where possible, maybe even post-mission. Have ideas of how exactly ready/trained.
MapleCan won't release MapleSeeds	6.00	100	6	This will be extensively tested for but maybe have a backup emergency mechanism triggerable from the ground station or when problem is detected to open up the MapleSat entirely and hope.
MapleCan communication will fail	12.00	80	9.6	Ask for advice with this, educate ourselves. Have an ACK signal?
MapleCan won't be recovered	3.00	70	2.1	Play hide and seek to test recovery system efficiency.

Mission Risk analysis 3/3

MapleSeed won't fulfill in-flight requirements e.g. descent rate	12.00	30	3.6	We will be penalized but mission data might still be good, losing one of the two seeds wouldn't be catastrophic. Take some 10-15% margin on requirements.
MapleSeed communication will fail	20.00	80	16	Ask for advice with this, educate ourselves. Have an ACK signal? Evaluate the conditions for the transmission to take place and release seeds to minimise failure probability. Choose to emit in a larger cone.
MapleSeed won't be recovered	12.00	40	4.8	Use camera footage to determine landing sites/flight directions.
Last minute problem won't be located on time	70.00	85	59.5	Have a backup system/components and tools. Have an automated testing procedure.

The risk analysis performed for the project allowed us to highlight the issues that could arise and categorize them with a **severity** score that is the product of the **probability** and the **consequence**. To lower problematic risks (those with the higher scores) we would have to work on lowering either or both the probability and the consequence. We also propose ways to mitigate those risks.