OHB System AG
J.-C. Meyer, M. Peukert
18.03.2015, ESTEC

SPACE SYSTEMS

OHB LEO Platforms and SDM requirements
CleanSat Workshop

We. Create. Space.

Contents

- OHB LEO Platforms
- Subsystem aspects of SDM
- Influences on P/F evolution
- Future technologies
- Conclusion

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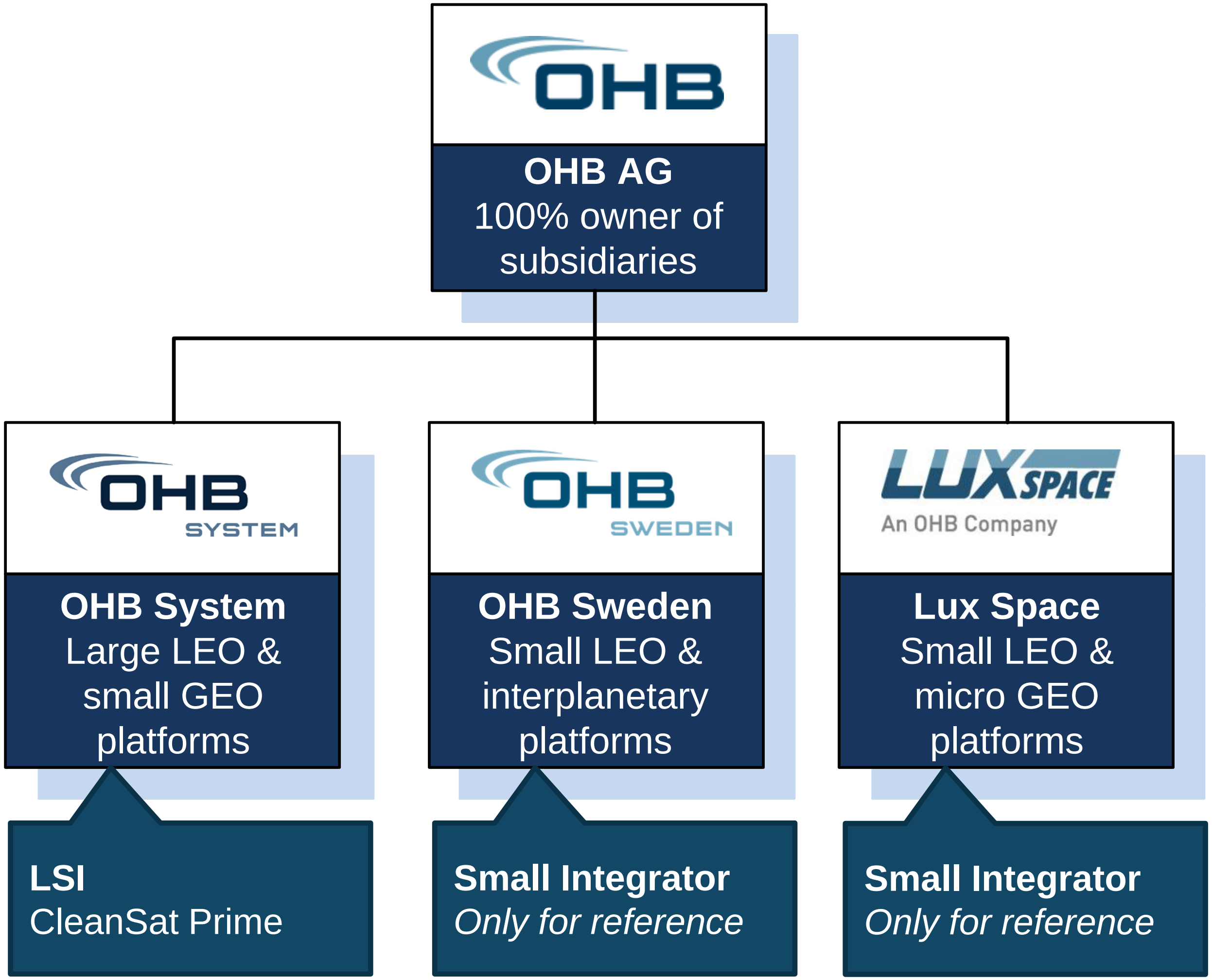
Platform Integrators within the OHB Group



OHB AG
100% owner of subsidiaries

OHB System
Large LEO & small GEO platforms

OHB Sweden
Small LEO & interplanetary platforms

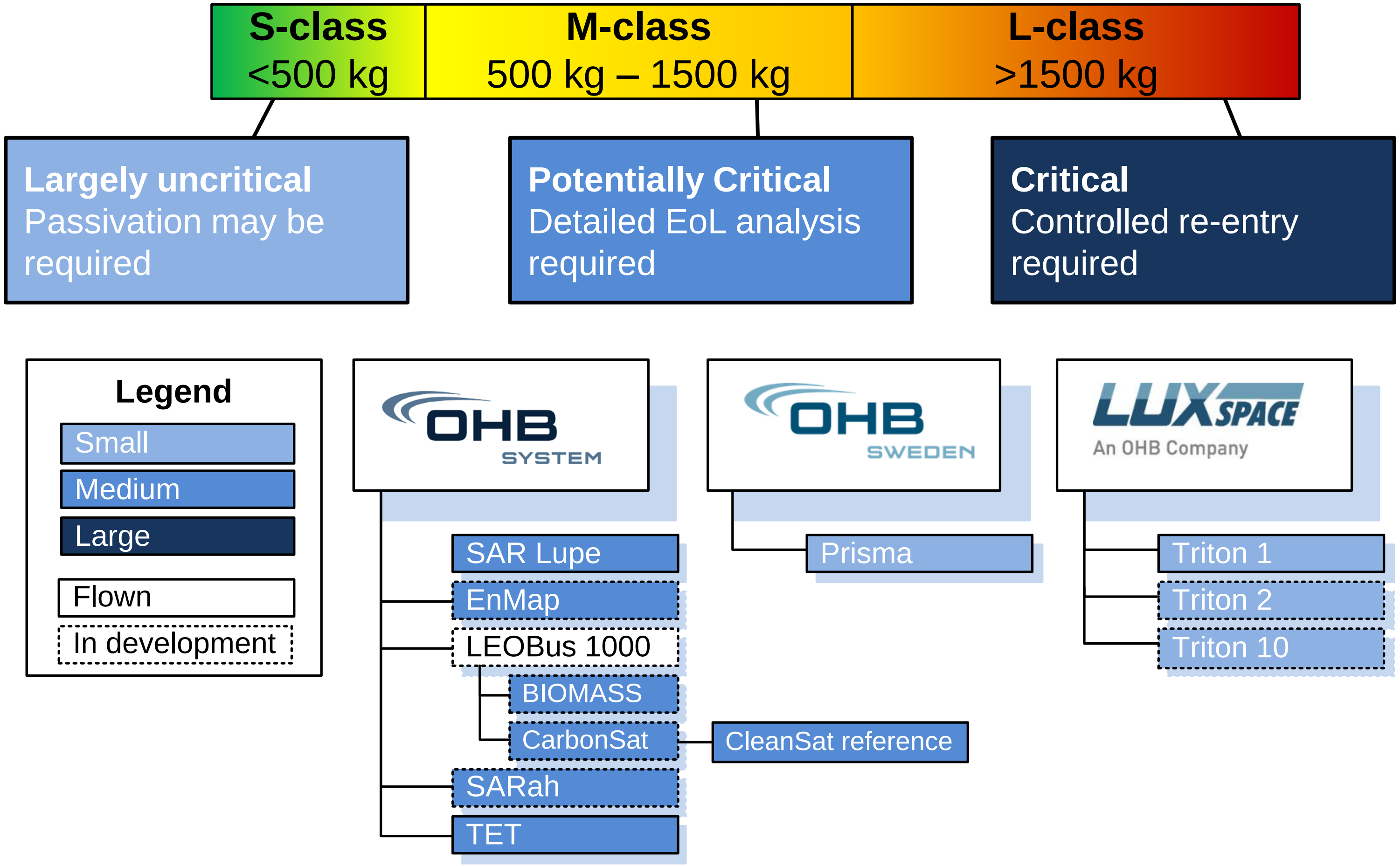
Lux Space
Small LEO & micro GEO platforms

LSI
CleanSat Prime

Small Integrator
Only for reference

Small Integrator
Only for reference

Classification of platforms



S-class
<500 kg

M-class
500 kg – 1500 kg

L-class
>1500 kg

Largely uncritical
Passivation may be required

Potentially Critical
Detailed EoL analysis required

Critical
Controlled re-entry required

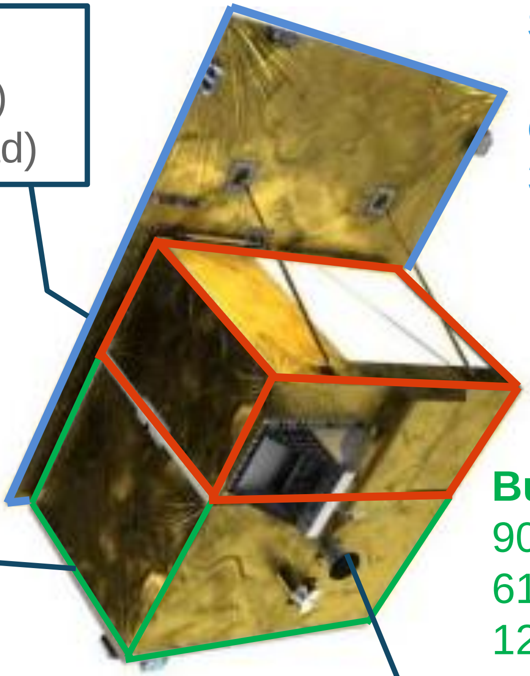
Legend
- Small
- Medium
- Large
- Flown
- In development

OHB SYSTEM
- SAR Lupe
- EnMap
- LEOBus 1000
  - BIOMASS
  - CarbonSat
    - CleanSat reference
- SARah
- TET

OHB SWEDEN
- Prisma

LUXSPACE An OHB Company
- Triton 1
- Triton 2
- Triton 10

EnMAP Overview



TT&C
S-band (TMTC)
X-band (payload)

Structure / Thermal
Al-honeycomb
Shear web
Passive thermal ctrl.

Solar Array
Fixed, with GaAs TJ cells
ca. 970 W / EoL
32 V unregulated bus
132 Ah Li-ion batteries (BoL)

Payload
353 kg
ca. 700×1800×470 mm³

Bus
90.6% reliability / 5 years (design life)
618 kg (wet), 563 kg (dry)
1280×1800×1470 mm³

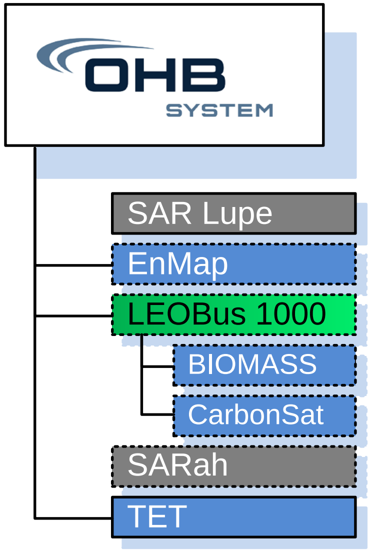
3-axis stabilized
Star trackers, coarse sun sensors, gyros, magnetometer, GPS, magnetorquers, reaction wheels

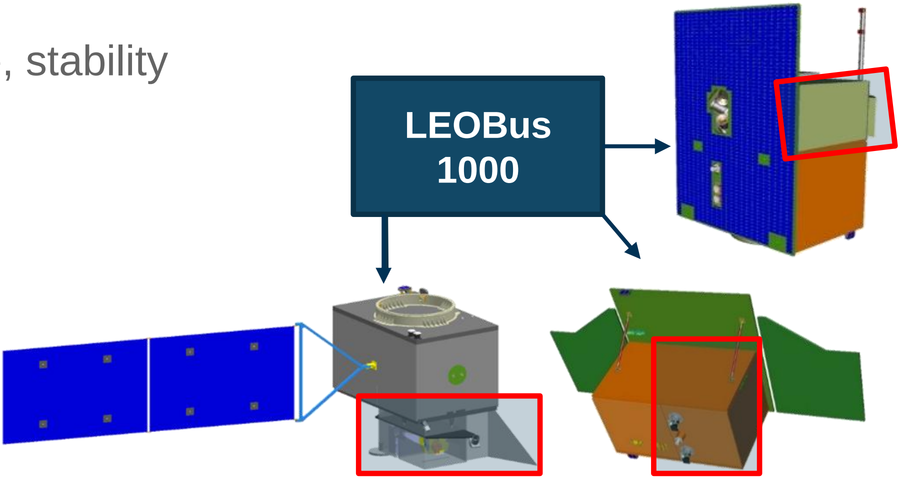
PSLV

653 km SSO

OHB System – LEOBus 1000

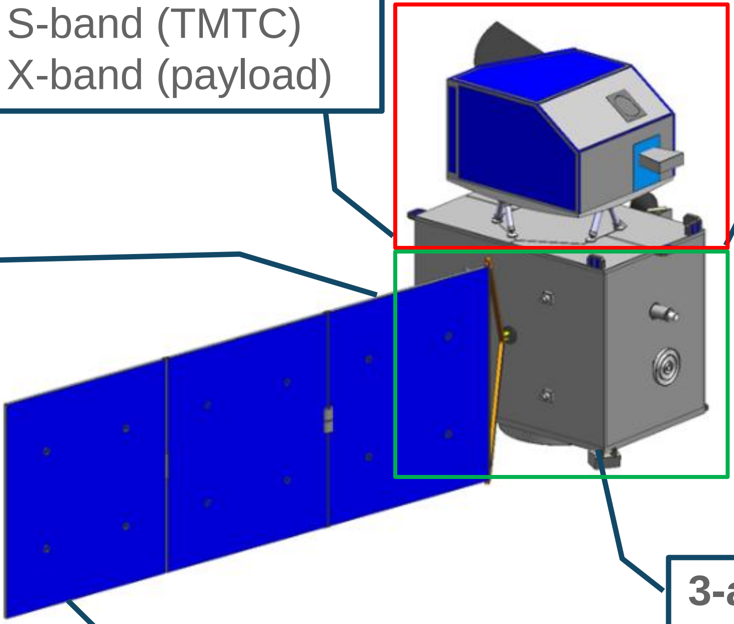
- **Increasingly competitive EO market → *standardization***
- OHB System's response: LEOBus 1000
- **Key features:**
  - Flexibility: power generation, accommodation / structure
  - Separation of payload and platform
  - Agile, high pointing accuracy, knowledge, stability
  - Very high rate payload processing chain





Payload modules

CarbonSat Overview



Structure / Thermal
Al-honeycomb
Shear web
Passive thermal control

TT&C
S-band (TMTC)
X-band (payload)

Propulsion
LEOBus 1000 system

Payload
209 kg (with margins)

Bus
904 kg (wet with margins)
847 kg (dry with margins)
91.3% reliability (5 years)

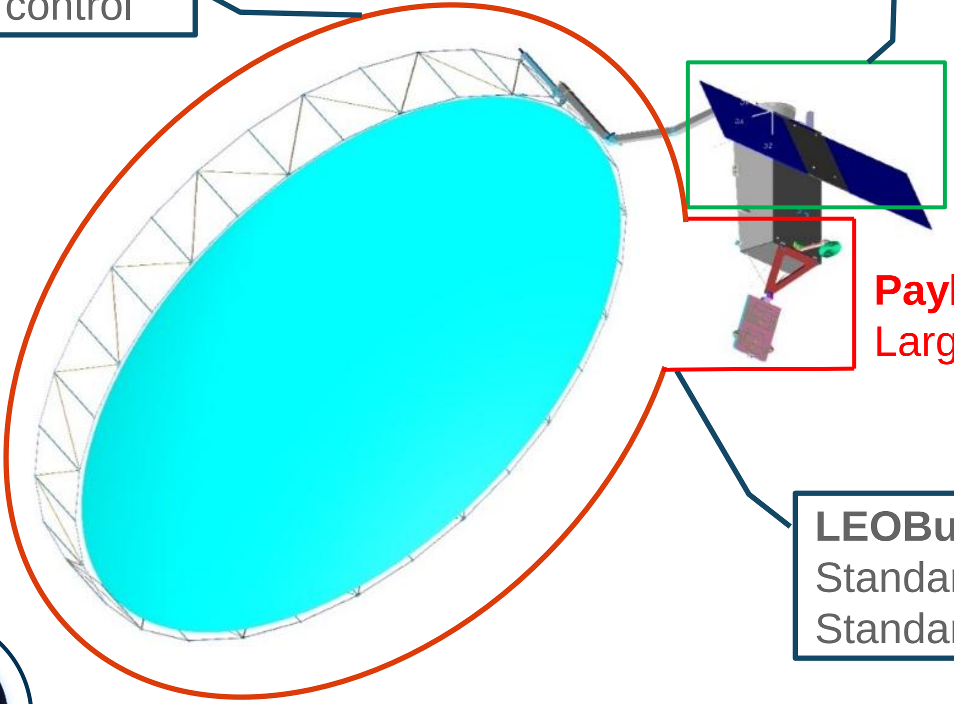
3-axis stabilized
Standard LEOBus 1000
avionics, gyroless

Electrical Power System
3 S/A panels and SADM
28 V unregulated bus, Li-ion batteries

Vega

594 km SSO

BIOMASS Overview



Structure & Thermal
Double-cross shear web
Passive thermal control

Electrical Power Subsystem
Deployable fixed S/A ~6.5m²
Li-ion cells

Bus
1200 kg (wet with margins)

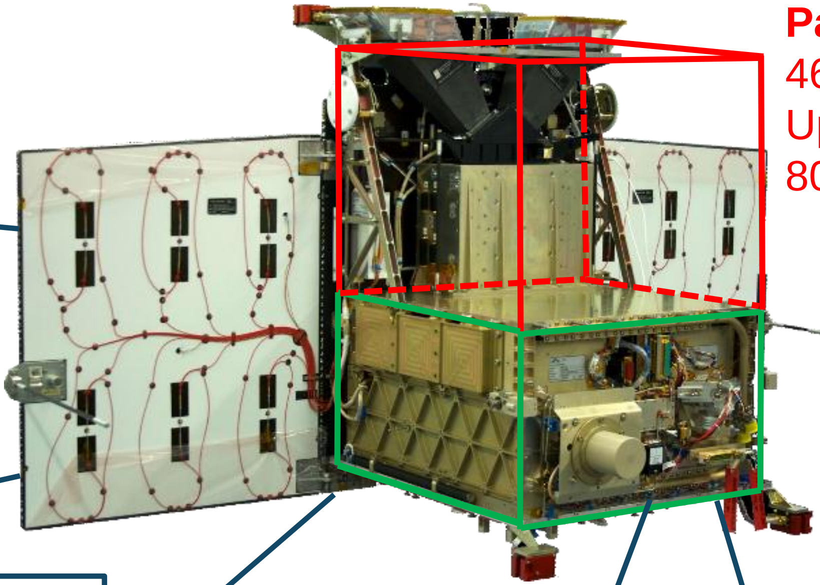
Payload
Large mesh reflector

LEOBus 1000-based
Standard avionics
Standard propulsion system

Vega

640 km SSO

TET Overview



2 solar arrays
TJ GaAs cells
NiH_2 battery

Structure
Aluminium with
CFRP elements

Thermal
Passive

S-band TT&C
LGA & HGA

3-axis stabilized
GPS, sun sensors, star trackers, magnetometers, IMU, reaction wheels, magnetorquers

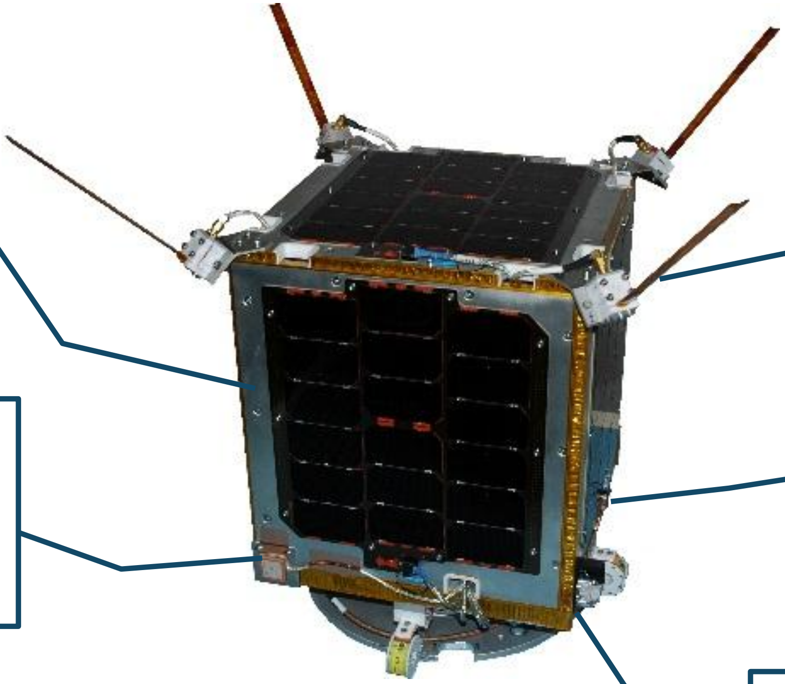
Payload compartment
460 × 450 × 428 mm^3
Up to 50 kg
80 W (peak), 20 W (nominal)

Bus module
Ca. 70 kg
95% reliability (14 months)
Up to 3-5 years lifetime
880 × 580 × 670 mm^3
No propulsion

Designed for piggyback, Soyuz baseline

450 km – 850 km
53° to SSO incl.

Triton-1



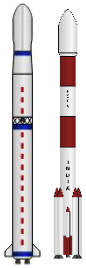
Structure & Thermal
30 cm Aluminium cube
Demisable
Passive thermal control

Electrical Power
5 panels, 2 × 9 TJ cells
3s2p Li-ion cells

TT&C
Redundant UHF
Backup through VHF (payload)

Attitude Control
None – tumbling P/F
Sun sensors, GNSS, magnetometer, gyros

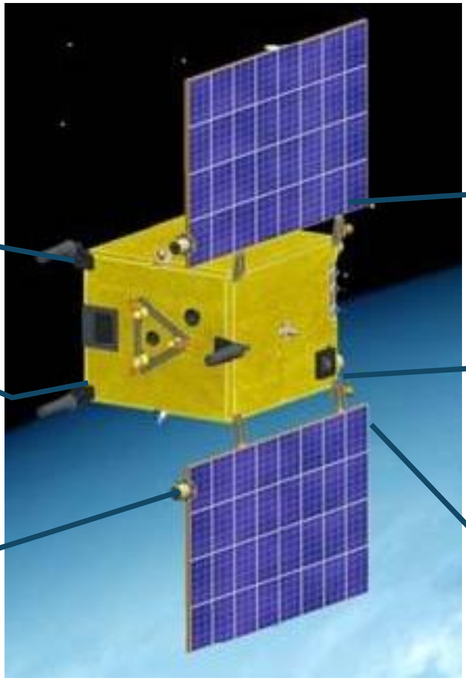
Platform
28.2 kg total dry mass
Ca. 4 kg payload mass
3 years design life
No propulsion



Flexible launcher
Flown LM 4B, PSLV

500 km SSO
870 km, 20° incl.

PRISMA Overview



Structure & Thermal
800 × 830 × 1300 mm³
Aluminium cuboid
Active thermal control

AOCS
3-axis stabilized
Translational RCS

TT&C
S-band to ground
UHF inter-satellite

Electrical Power
40 W payload power
28 V regulated bus
Li-ion battery

Platform
150 kg (wet), 139 kg (dry)
31 kg (payload)
SPF tolerant
2 years design life

Propulsion
3 systems:
HPGP (70 m/s),
hydrazine (150 m/s),
MEMS

Flexible launcher
Flown on Dnepr

725 km dusk-dawn SSO

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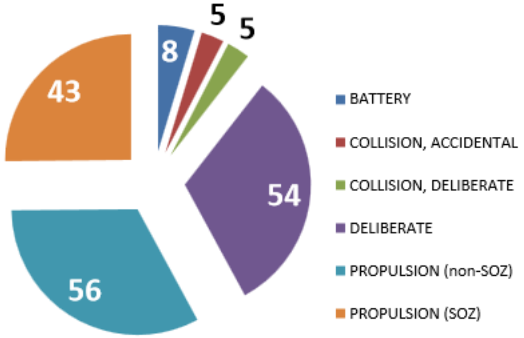
The Two Main Debris Sources

- Database 232 break-up events in orbit (1958 – present)

Rocket-Propulsion: 96 Upper Stage Failures

- 115 Satellite Break-ups (40 over the last 25 years)
- 4 Major Satellite Break-up Root Causes
    - Self-Destruction, Collision, Battery, Propulsion

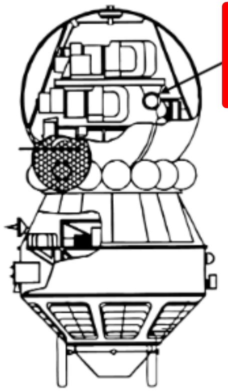


Known-Cause Break-ups (NASA)

- Total of 54 Deliberate Satellite Self-Destructions

SAT Self-Destruct: 52x COSMOS (by APO-System)

- Deliberate satellite destruction due to
    - Mission termination
    - System malfunction or payload recovery failure
    - Weapon test



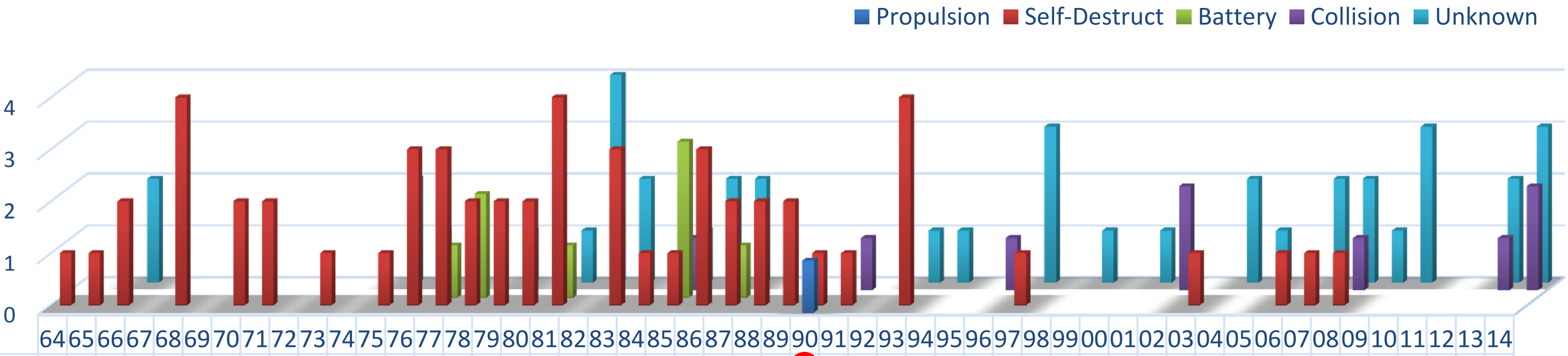
APO system incl. **10kg** TNT

COSMOS: Zenith 2 class

History of Satellite Break-up

- We are dealing with SAT-Deliberate and Rocket upper-stage break-ups in LEO
- Satellite-Collisions and Unknown causes increase as a result

Deliberate Debris



	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89
🟦 Propulsion																										
🟥 Self-Destruct	1	1	2		4		2	2		1		1	3	3	2	2	2	4		3	1	1	3	2	2	2
🟩 Battery														1	2			1				3		1		
🟪 Collision																						1				
🟦 Unknown			2									2	1	1		1		1	4	2		1	2	2		

	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14
🟦 Propulsion	1																								
🟥 Self-Destruct	1	1		4				1						1			1	1	1						
🟩 Battery																									
🟪 Collision		1					1						2						1					1	2
🟦 Unknown				1	1			3		1		1			2	1		2	2	1	3			2	3

USA 68

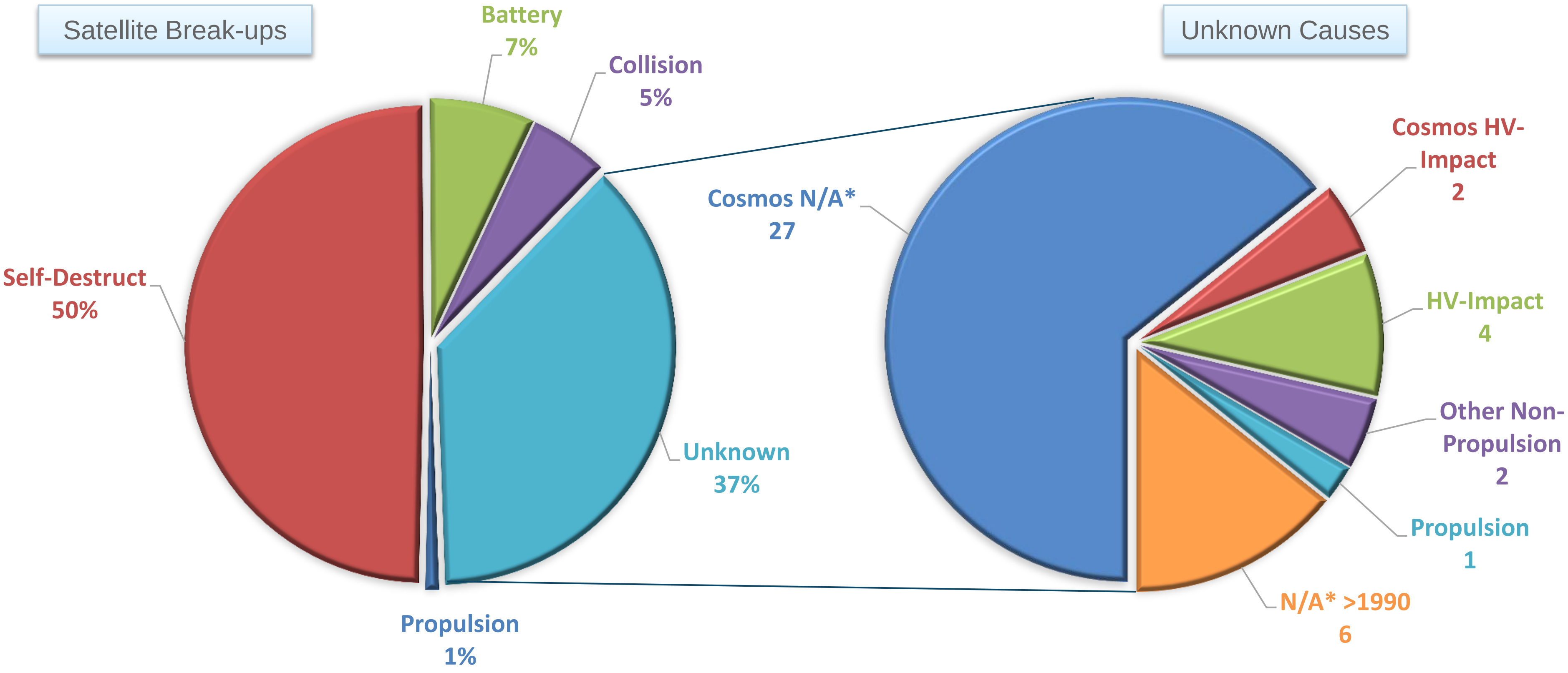
USA 73: Possible Residual Propellant

1 confirmed propulsion break-up: USA 68 solid rocket kick-stage

Uncertainty of Propulsion Induced Satellite Break-up

Satellite Break-ups

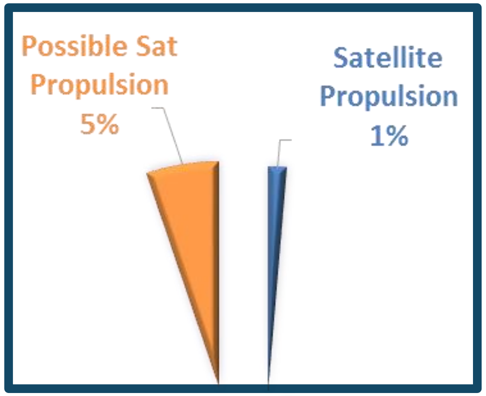
Unknown Causes



9 COSMOS break-ups over the last 25 years possible propulsion

* N/A = Insufficient Data

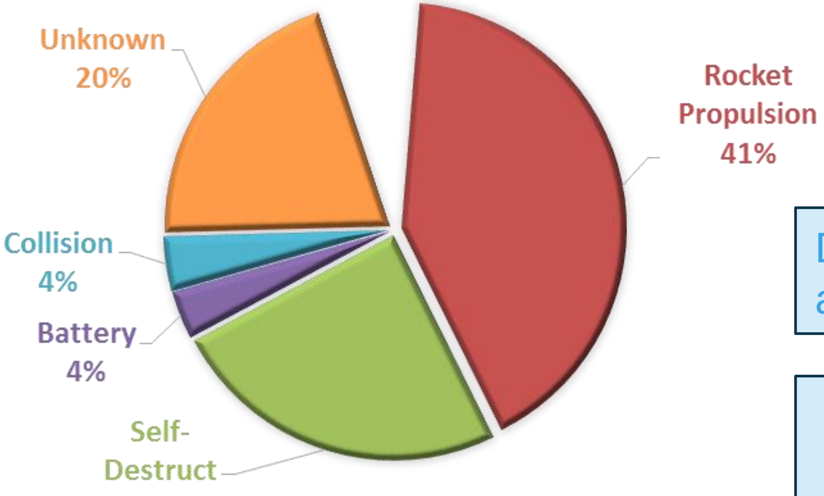
Does Satellite Passivation promise a decisive benefit?



Negligible Impact of Satellite Propulsion

Out of 115 Satellite break-ups for propulsion:

- 1 confirmed case (USA 68 solid-rocket kick-stage)
- 1 possible case (USA 73 liquid propulsion system)
- 9 unknown cases (COSMOS)
- 6 other unknown cases (US, China, …)



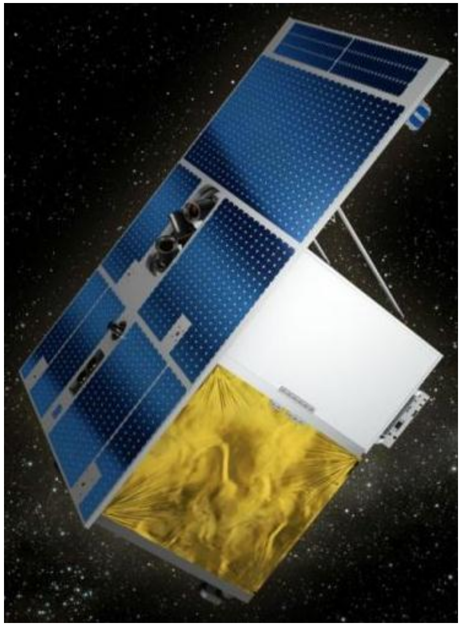
Overall Break-up Share

Data indicates Satellite Liquid Propulsion S/Ss are technically safe within 25 years in-orbit.

Only minor Satellite Propulsion Contribution to break-ups found.

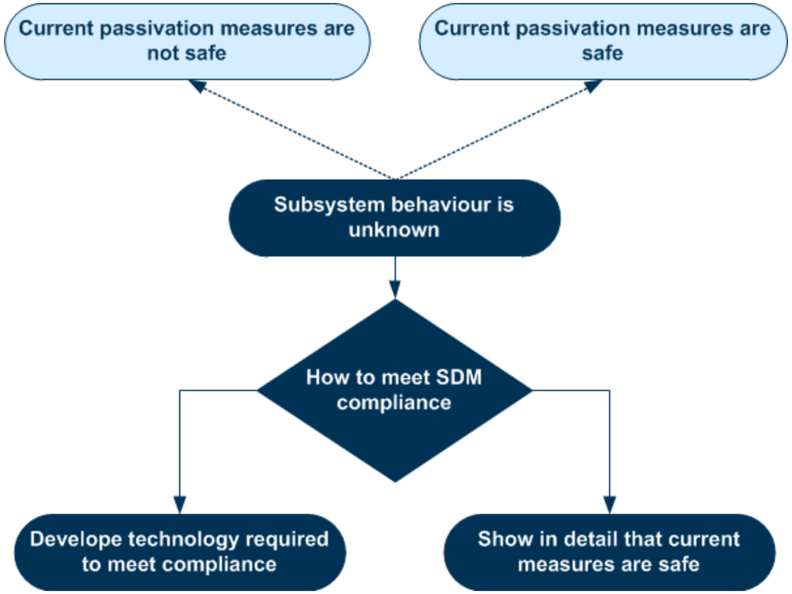
Electrical Power Subsystem Passivation

- There have been at least 8 known break-ups of spacecraft due to batteries
    - All incidents occurred with pre-Li-ion technology (e.g. Ni-Cd or Ag-Zn)
- Modern Li-ion batteries have several protection mechanisms that shall avoid explosions
- Nevertheless, explosions do remain a known failure mode
- Risk reduction of break up with
    - Controlled depletion of the stored energy from batteries
    - Disconnection from the solar array



Two Paths to comply with Space Debris Mitigation

- Current passivation measures for power and propulsion subsystems are doubted to be safe
- Two perspectives:
  - Safety after EoL has never been proven
  - With current passivation measures no failures have been observed
- To come to an agreed solution two possible paths exist:
  - Technology development
  - Studies on the safety of state-of-the-art


Current passivation measures are not safe

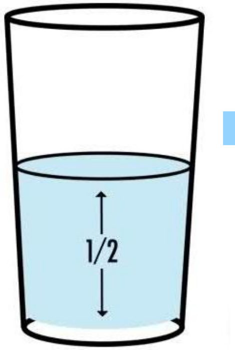
Current passivation measures are safe

Subsystem behaviour is unknown

How to meet SDM compliance

Develope technology required to meet compliance

Show in detail that current measures are safe



How to show compliance in general?

Passivation of Other Subsystems

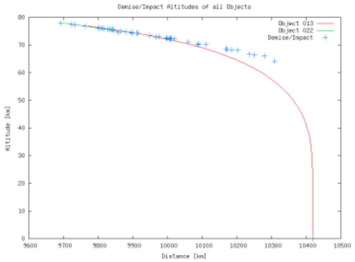
Example

	Reaction Wheels	Heat Pipes	Cryo Cooler
Reliability	99.8%	100%	99.8%
Failure modes	Mechanical or electrical failure	Ammonia leakage	Failure of pressurized part
Worst case effect	Damage to inner spacecraft parts and debris generation	Degradation of thermal control performance and corrosion of hardware	Loss of cooling capacity and Helium leakage or burst
Mitigation efforts	■ Fail safe design ■ Safety factor ■ Structural tests	■ Safe life design ■ Safety factor	■ Margins / safety factor ■ EoL design ■ Structural tests
SPF	no	yes	no
Passivation	noncritical	noncritical	noncritical

Casualty Risk Analysis - Results

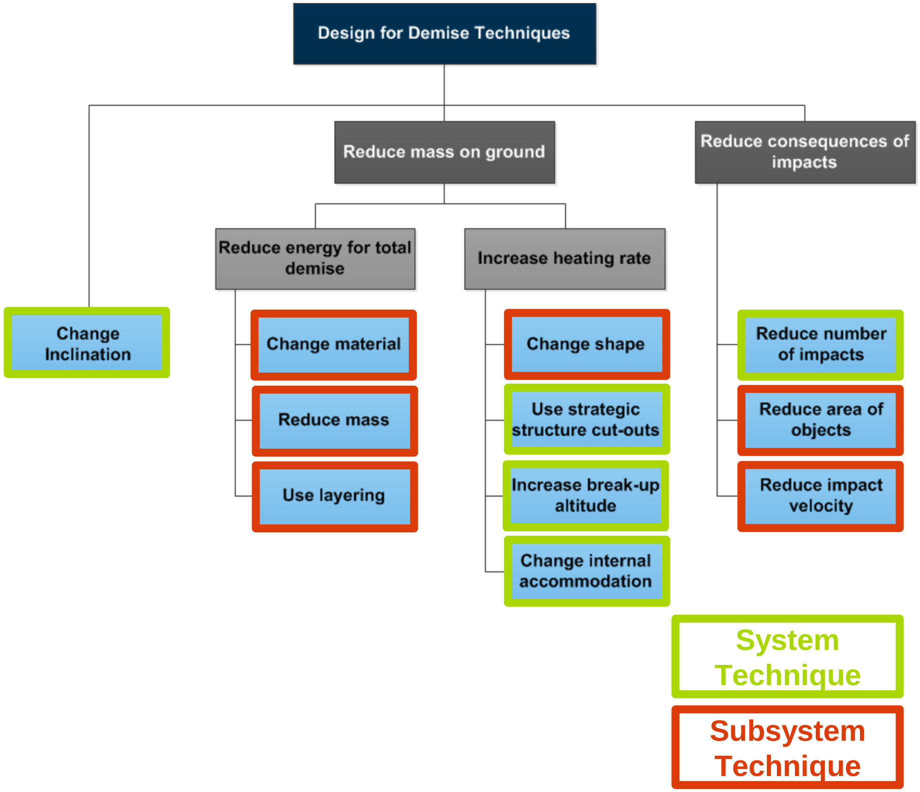
Example

- Example case of typical LEOBus-1000
  - Total mass ~1000 kg
- Casualty analysis shows only surviving fragment is the spacecraft tank:
  - Titanium alloy has a high melting point
  - High area-to-mass-ratio at the end-of-mission when the tank is empty
- Total casualty risk calculated by DRAMA is 3.33x10^{-5}
- **SDM compliant for uncontrolled re-entry scenario**



Casualty Risk – Critical Platform Elements

- System-level D4D techniques in general have complex, mission specific consequences
- Subsystem-level D4D techniques can be applied by component manufacturers
- Critical components include
  - Tanks
  - Reaction wheels (flywheel)
  - Magnetic Torquer Cores



Design for Demise Techniques

- Change Inclination
- Reduce mass on ground
  - Reduce energy for total demise
    - Change material
    - Reduce mass
    - Use layering
  - Increase heating rate
    - Change shape
    - Use strategic structure cut-outs
    - Increase break-up altitude
    - Change internal accommodation
- Reduce consequences of impacts
  - Reduce number of impacts
  - Reduce area of objects
  - Reduce impact velocity

System Technique

Subsystem Technique

- OHB LEO Platforms
- Subsystem aspects of SDM
- **Influences on P/F evolution**
- Future technologies
- Conclusion

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Two trends influence future LEO platforms

Technology Developments

Push

LEO Satellite Platforms

Pull

Mission Requirements

Two trends influence future LEO platforms

Technology Developments

Push

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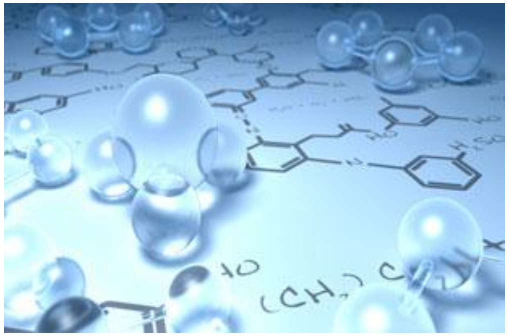
Pull

Mission Requirements

REACH

- REACH is the Regulation on Registration, Evaluation, Authorization and Restriction of Chemicals
- Aim is to ensure a high level of protection of human health and the environment from the risks that can be posed by chemicals
- In the space sector used chemicals Hydrazine & Chromium VI are Substances of Very High Concern (SVHC) on the candidate list for banning according to the REACH law
- Hydrazine is the biggest issue here as it is used extensively as a propellant for upper stages and satellites
  - Earliest sunset date is 2019



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Technology development drivers

- Biggest technology drivers for platforms are:
  - Additive manufacturing to reduce structure mass and cost
  - MEMS technology to reduce mass, volume and power requirements
  - Increased use of electric propulsion to reduce propellant mass
  - Higher efficiency solar panels and/or flexibly thin-film solar panels
  - Super conductors for application in Magnetorquers & Momentum wheels
  - Harness reduction techniques using optical fibres, wireless sensors, Fiber-Bragg Grating sensors and powerline communication

http://www.sunconnect.com.au

Performance improvements of future LEO platforms

- Most technologies aim to decrease mass & cost and increase performance
- In the future the platform part of a satellite will decrease in mass enabling higher performance payloads
- Or for the same performance the satellite can be launched by a smaller (= cheaper) launcher

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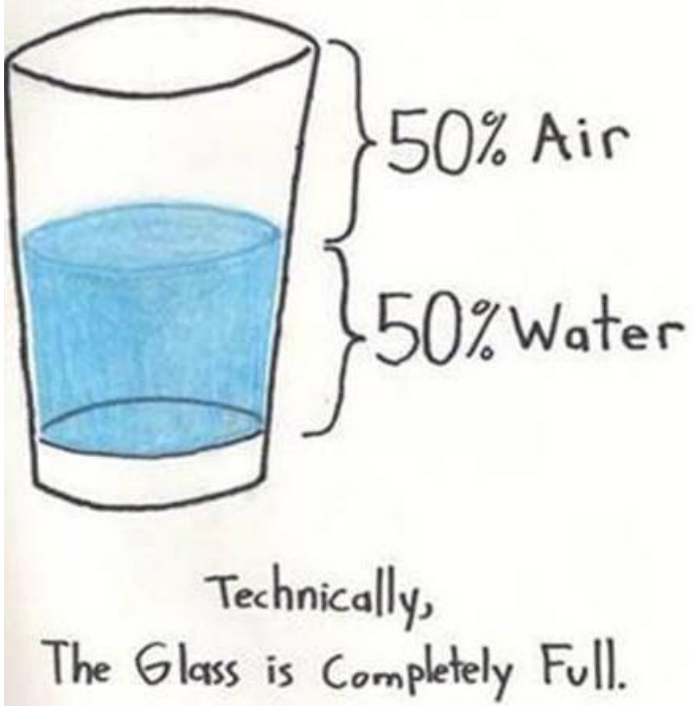
Conclusions

- Different sets of SDM standards applicable to OHB group LEO missions
- If interpreted strictly certain non-compliances to ESA IPOL 2014 SDM requirements exist
- How to obtain the “ESA SDM requirements verification guidelines”?
  - Currently, SDM compliance analyses have too many undefined parameters
- Critical technologies or areas of investigation are currently studied in detail
- Outcome of the CleanSat study will be a ranked list of technologies to be developed or research to be done



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