DRACO
(Destructive Re-entry Assessment Container Object)

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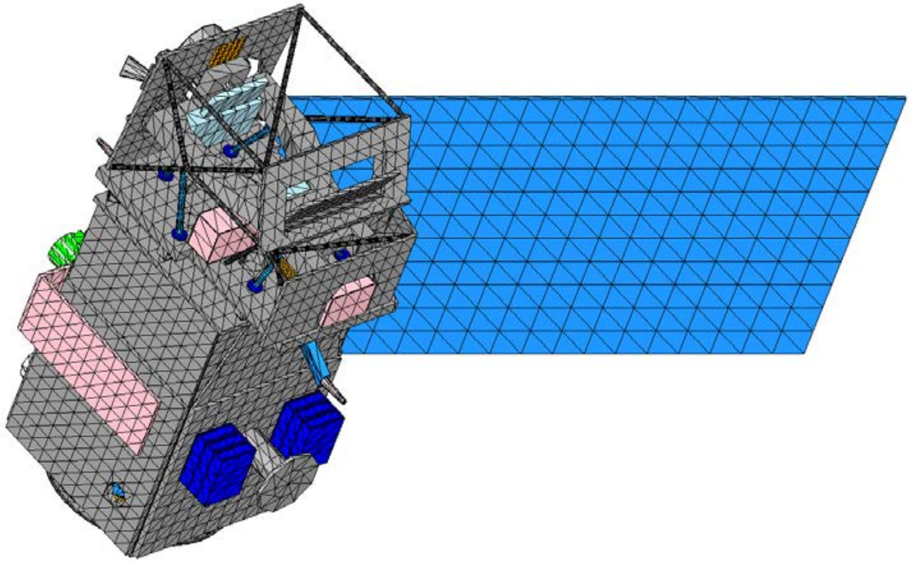
2021 Clean Space Industry Days

21/09/2021

The ideal world

From a digital satellite model to a validated physics simulation

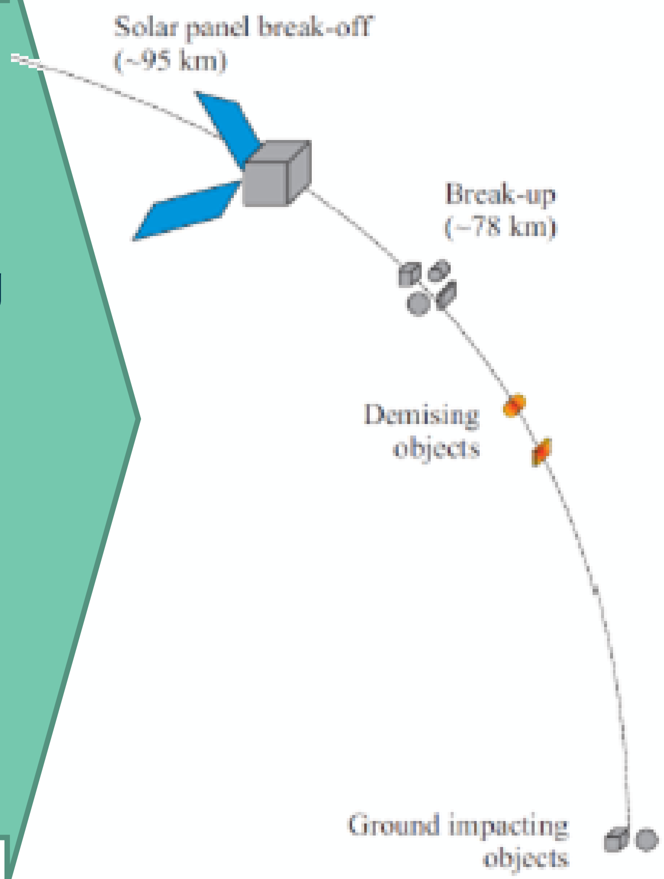


The ideal world – The current reality

From a digital satellite model to a validated physics simulation

- ~10 qualified materials
- Aerothermodynamics for ~5-10 simple shapes
- Ground facilities limited to testing small (~cm/dm) sizes

- Realistic simulations are beyond computation reach
- “real” ground fragments are partially predictable
- Components are small systems themselves



Scope

Problem statement

- The **physics** of the destructive break-up process of large space objects in the Earth atmosphere **is poorly understood**.
- **Ground-experimentation** is **limited** in size and not fully representative; **Remote and in-situ** observations are **beyond rudimentary predictive capabilities**.
- This implies risk assessments that are based on procedures **with large uncertainties**.

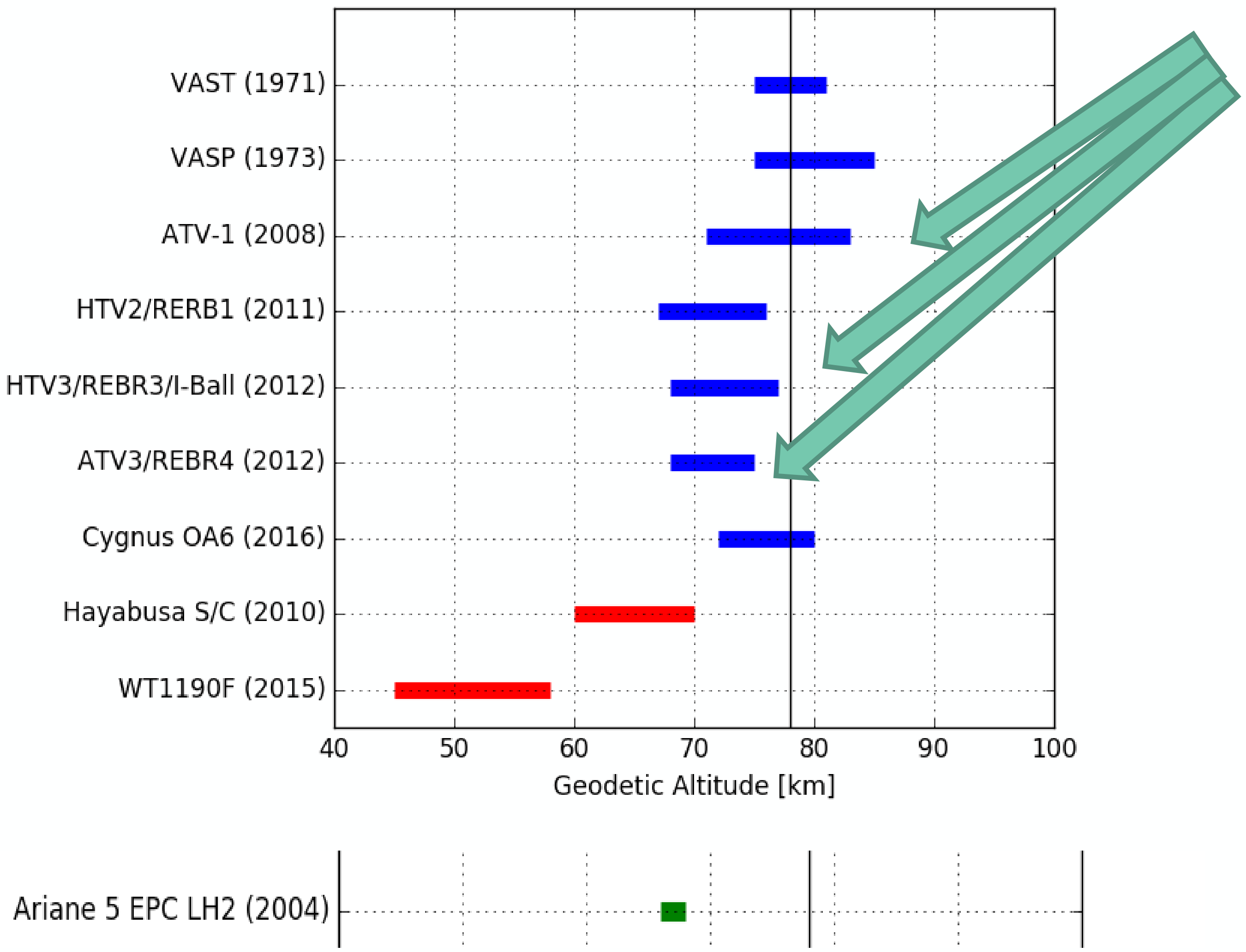
Needs

- Large uncertainties imply the need of **repeatable experiments.**
- Small scale physics can be **extrapolated from ground-testing**, but is not confirmed on relevant scales.
- The **physics** of a **destructive controlled re-entry** is not better understood than an uncontrolled case.

Objective

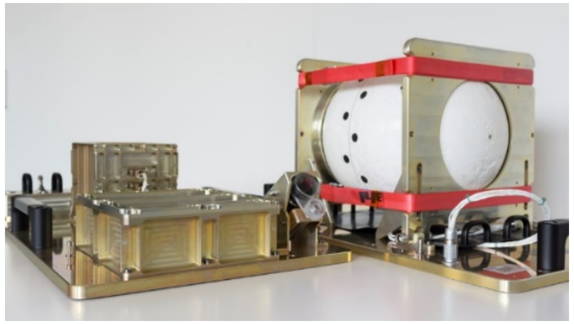
Design a platform with components representative for large scale systems that can be instrumented by a device that survives the re-entry and can transmit the data for analysis on-ground.

Haven’t we done this before?



Break-up recorders:

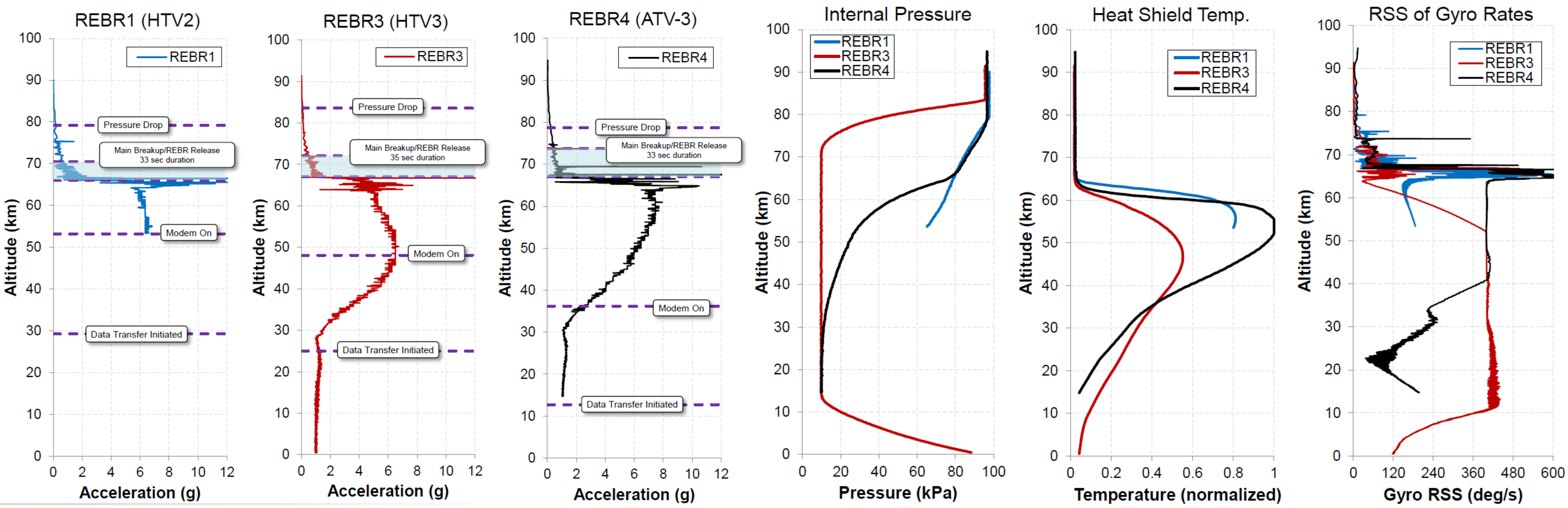
- Making in-situ observations of the acceleration, pressure and temperature during a re-entry event. (however, such data can’t be simulated for the destructed object)
- These sensors have been installed on cargo vessels for the International Space Station.
- Of the seven models used to date, three REBR models have consistently returned data.
- Controlled, i.e. non-neglible γ



Haven’t we done this before?

REBR/I-Ball/BUC (defacto - State of the Art)

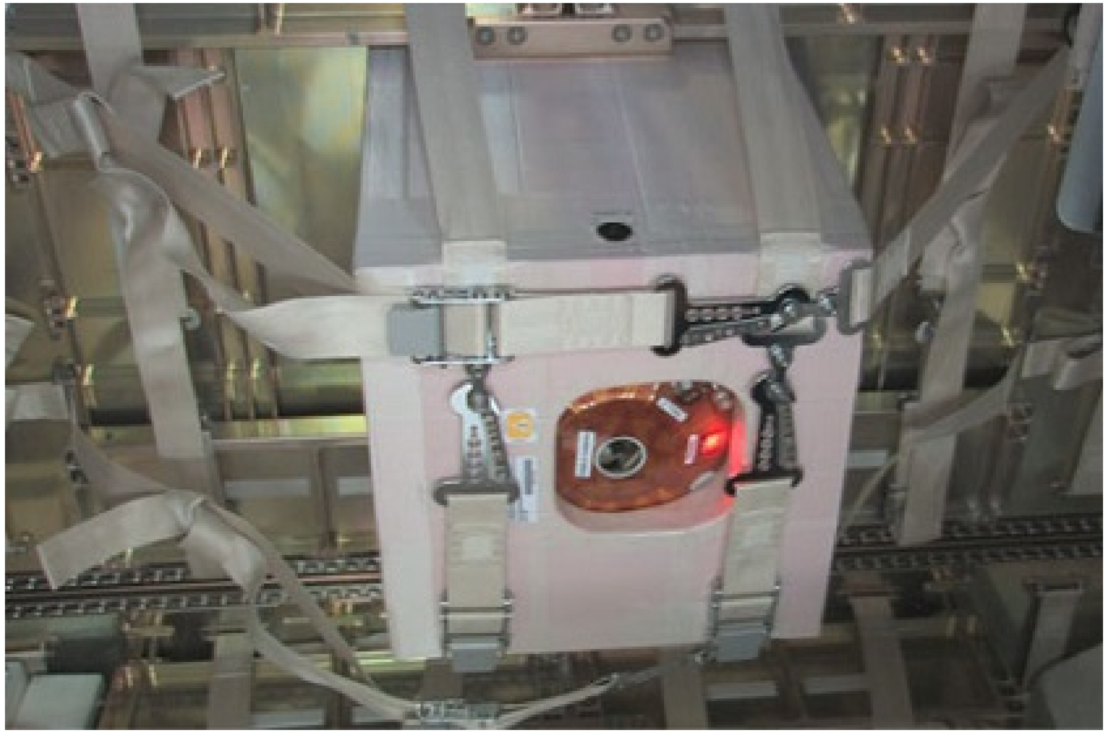
Images Credit: Comparison of Reentry Breakup Measurements for Three Atmospheric Reentries – Feistel, Weaver, Ailor – 6th IAASS Conference: Safety is Not an Option, May 2013. http://articles.adsabs.harvard.edu/pdf/2013ESASP.715E..75F



Haven't we done this before?

REBR/I-Ball/BUC (defacto - State of the Art)

Images taken from: https://iss.jaxa.jp/en/kiboexp/theme/iball/index.html Re-entry photo data sent from i-Ball (HTV3)(Credit: JAXA).



Haven’t we done this before?

CSID 2016: SATCOM Re-entry Kit

CSID 2017: Demise Observation Capsule: Progress update

CSID 2018: Initial Considerations for Re-entry Breakup Experiment

Shift of focus, from opportunistic capsule (instrument) to experiment (platform)

5ISDRW, Conceptual design of a re-entry analysis platform for investigation of space debris

5ISDRW, A CubeSat for demise investigation – SOURCE

5ISDRW, Re-entry Break-up Experiment Assessment

Scope (Phase 0 Study)

Focal points:

- **Early fragmentation** of the system (drives the follow-up events, is in the measurable range)
- Make the **platform collaborative** to ensure the data can be interpreted in a fail safe manner
- **Demonstrate demise improvements** by comparing to an understood baseline

Constraints

- **Limit costs** and bespoke technology developments (excluding D4D)
- Representativeness for a “real” situation, i.e. re-entry trajectory (**low fpa**) and satellite set-up (**large system**)
- Launch soon (mid decade)
- Consider the break-up **recording instrument** as a **black box**, and focus on the interfaces

Drivers

Mission

- Launch in ~2025
- Launcher:
  - Ariane 6 / Vega (baseline) or any credible European microlauncher
- Initial orbit: ~ SSO @10:30, 500-600 km (TBC)
- Satellite class: 100-200 kg (target)
- Entry flight path angle:
  - as shallow as possible, but controlled
- Excluded:
  - Cubesats, uncontrolled re-entry, ballistic flights

System

- COTS, representative scale and configuration
- Direct instrumentation within S/C:
  - Connected to survivable capsule,
  - Potential desire for capsule recovery
- High data volume for capsule vs. low data rate for down-/return-links (TBC)
- Instrument calibration for break up event
  - Visual and IR cameras
  - Sensors (mimick windtunnel setup)
- Configuration
  - Re-entry strategy,
  - Capsule mass/volume sizes the platform
  - Mass, volume, to fit in VEGA SSMS (critical)

Mission options

- **Option 1:** “deluxe” (/full) system
  - Controlled re-entry performed by S/C
  - Additional strawman payload (some days/weeks/months days/months in orbit)

- **Option 2: hybrid** (limited system functionality)
  - “Immediate” Controlled re-entry performed by S/C
  - Services in orbit Re-entry experiment with active equipment that can also be used in the test of demise
- **Option 3: reduced** (dummy system functionality)
  - Direct injection from launcher upper stage into re-entry trajectory
  - Services in orbit provided by Upper stage (e.g. AOCS and Deorbit manoeuvre, telemetry/ power umbilical)

- Option 2.5: dummy system with the controlled re-entry implemented via a Deorbit Kit

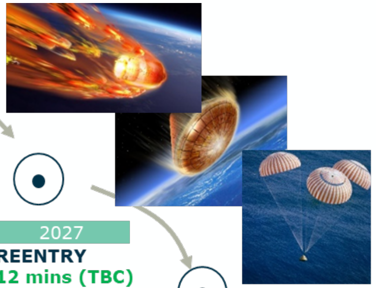
Mission profile, timeline & phases

JAN 2027
LEOP & DE-ORBIT PREPARATION
Reduced option: 0 days
Hybrid option: 4 days (TBC)

JAN 2027
LAUNCH – European Launcher
TBD

Mission Phases

1. LEOP and De-Orbit Preparation
2. Re-entry:
   - Platform enters and starts to heat (~120 km)
   - Platform fragmentation, capsule release (~80 km)
   - Blackout (TBC when) (~50-70 km)
3. Descent (from moment that start transmitting)
   - Capsule starts transmitting (~50 km - TBC)
   - Parachute deployment if available (1 case only) (~17 km - TBC)
4. Floating + recovery (TBC, 1 option only)

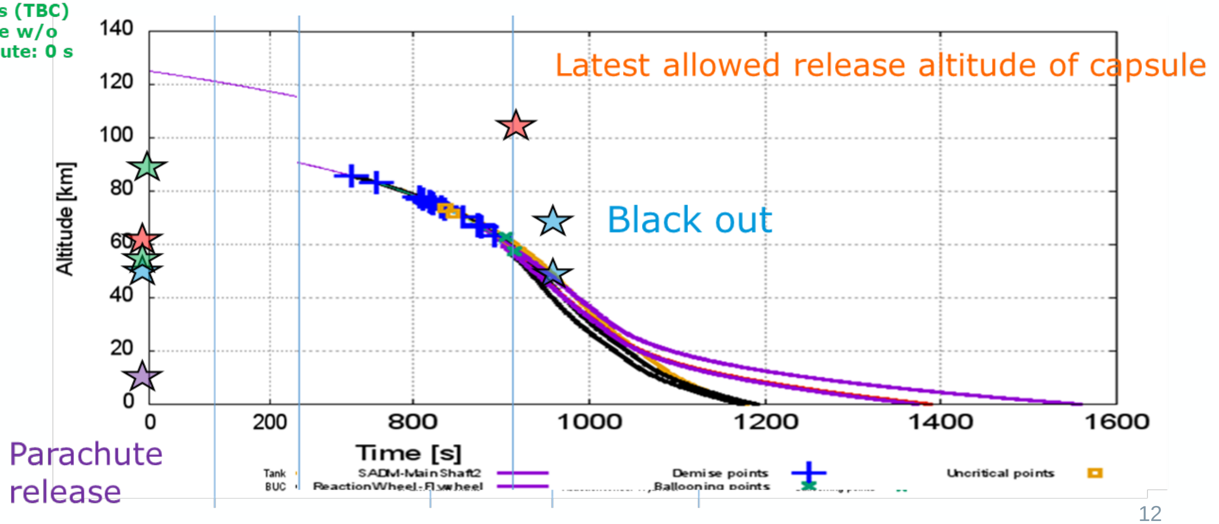


2027
REENTRY
12 mins (TBC)

2027
DESCENT
Capsule w/ parachute: 731 s (TBC)
Capsule w/o parachute: 375 s (TBC)

2027
FLOATING + RECOVERY (TBC)
Capsule w/ parachute: 3 hours (TBC)
Capsule w/o parachute: 0 s

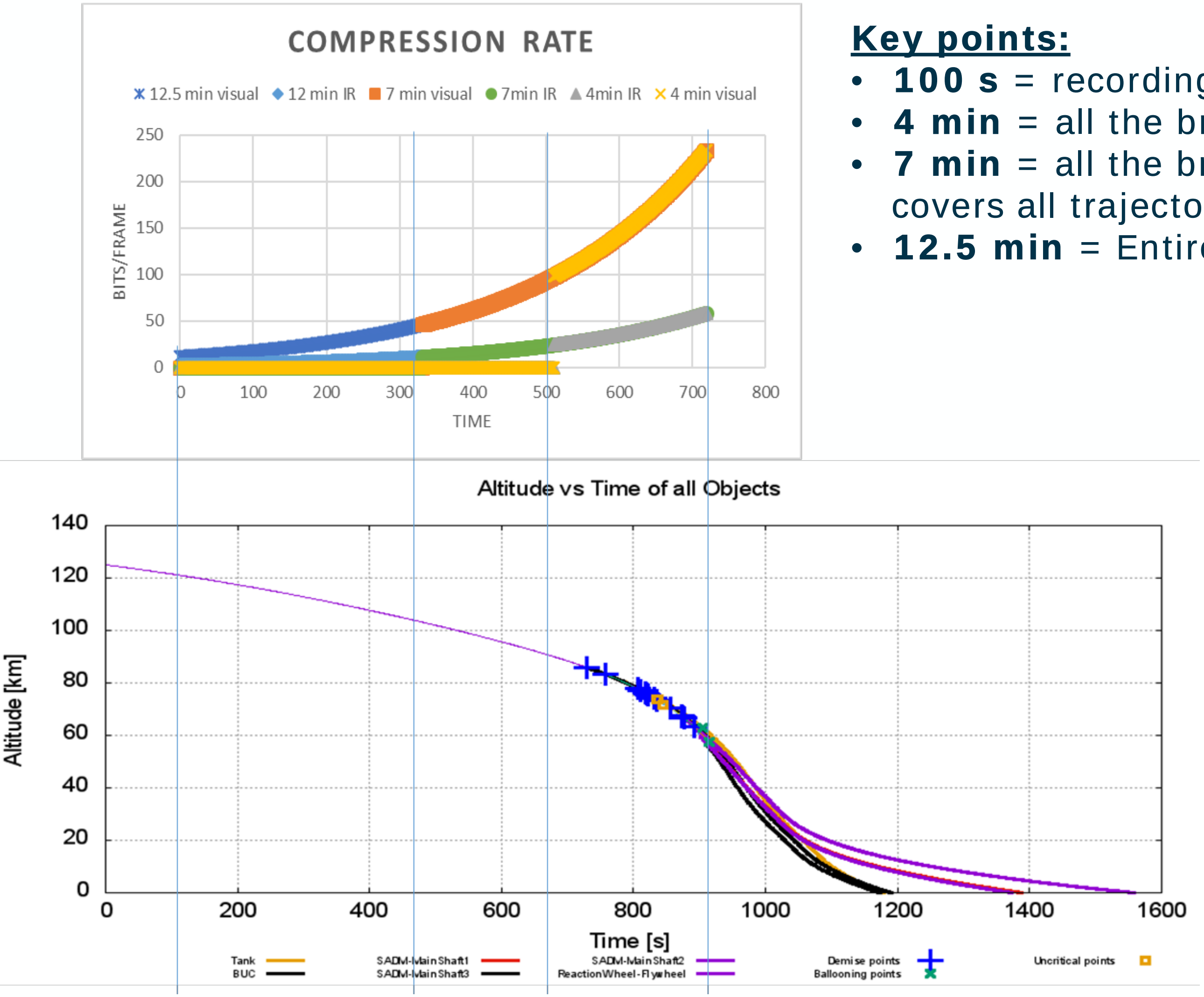
Target perigee ~ 50km
Achieve break-up before



Data capture

	Priority ranking for D4D objectives	Scalable? [Y/N]	Mass each [kg] (non-scalable only)	Mass impact ranking	Volume impact ranking	Availability / possibility to use available models (EM, dummys, etc)	Hybrid S/C	Dummy S/C
Weighting factors	**5**	**n/a**	**n/a**	**3**	**3**	**n/a**		
Structural panel (inc. demisable joints)	4.2	Y		5	5		Functional	Functional
Tanks (soft preference for titanium (due to prior experience), spherical)	4.2	Y (bigger than 10cm)		3	2		Functional	Dummy
Tanks demisable	5	Y (bigger than 10cm)	5kg (52l); 18kg (220l); COPV: 6kg (30l)	3	2		TBD	Dummy
Magnetotorquer (part of it)	4.2	*Y* (can use shorter length)*	6.7kg	4	4	EM	Functional	Dummy
Magnetotorquer demisable (part of it)	3.8	*Y* (can use shorter length)*	7.4kg (1m long) – can use pierce of	4	4	EM	Functional	Dummy
Reaction Wheel	4.2	N	10 kg (inc bracket)	2	2	EM	Dummy	Dummy
Reaction Wheel demisable	4.2	N	10 kg (inc bracket)	2	2	EM	Dummy	Dummy
Solar Array Drive Mechanism (SADM)	3.8	N	10 kg (Excl. yoke, panel). Potentially down 3 kg.	2	2	EM		
SADM demisable	4	N	10 kg (Excl. yoke, panel).	2	2	EM		
Electronic Card (Box / at unit level)	3.2	Y		2	2	EM	Functional	TBD
Battery (module/ unit level)	3.6	Y		2	2	EM	Functional	TBD
Demisable joints	5		Possibly no delta-mass	5	5		Functional	Functional

Data recording



Sensors – 12.5 min

Key points:

- **100 s** = recording only the main breakup
- **4 min** = all the breakup (no margin)
- **7 min** = all the breakup plus margins (e.g. covers all trajectories + uncertainties)
- **12.5 min** = Entire re-entry

 # Sensors (TBC):

Temperature sensors → 156

Joint-contact switches → 44

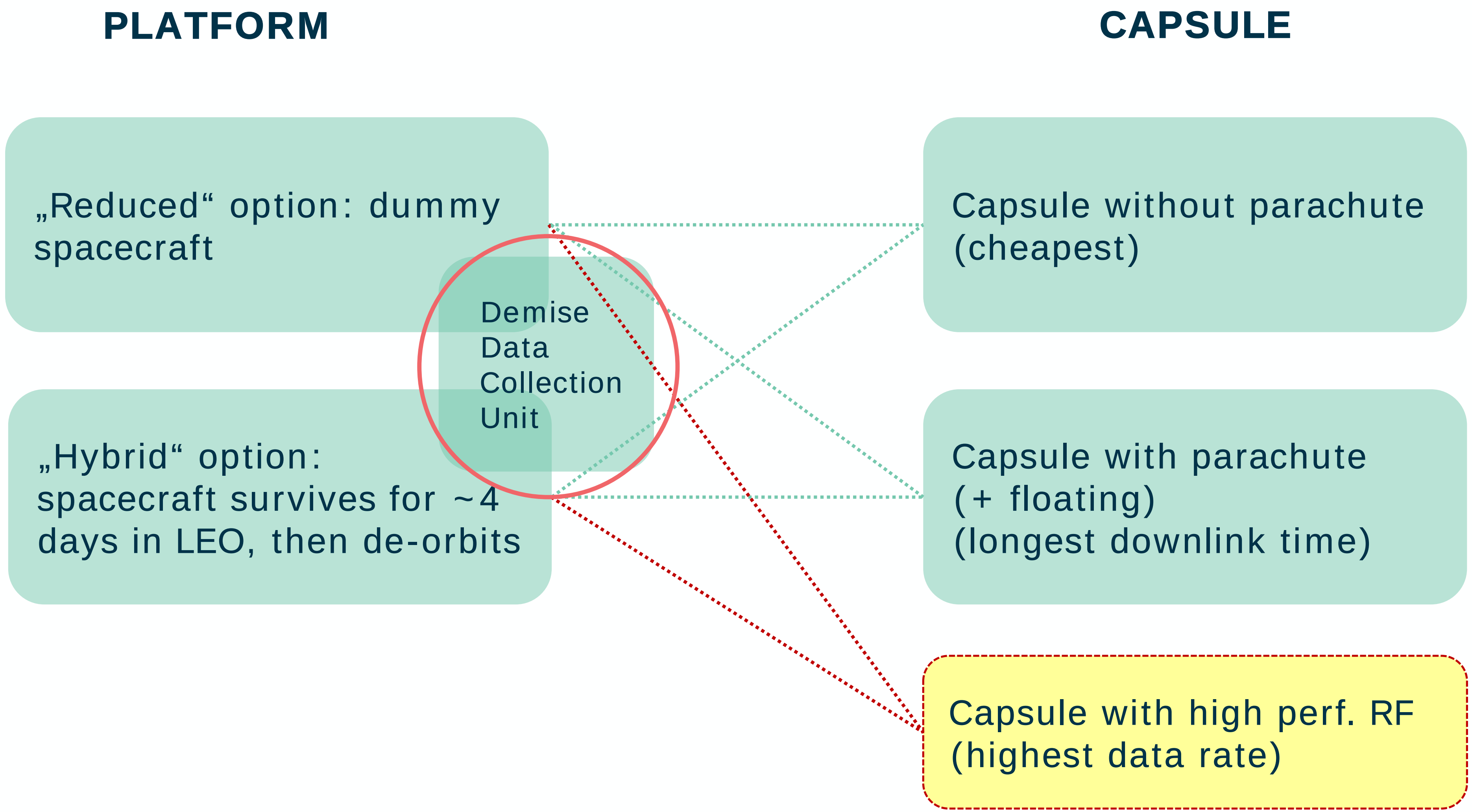
→ Total **analogue**: 200

	100 s	4 min	7 min	12.5 min
Cameras	**Compressed video + sensors (Mbits)**			
LR camera	5.94	7.34	8.87	10.38
HR Camera	7.71	15.94	22.01	28.04
LR + HR camera	9.19	18.82	26.41	33.96
2 LR + 2 HR camera	13.91	33.17	48.37	63.46

Data Transmission

Space asset or other?	Asset / strategy	Maintained [Y/N]
SPACE	Iridium	Midband [Y], Broadband [TBD]
SPACE	Inmarsat SwiftBroadband UAV	Y
SPACE	TDRS	N
SPACE	OneWeb, Starlink, etc	N
SPACE	EDRS	N
Ship	Deployable antenna	N
Ship	Recovery	TBD
Ground	Deployable antenna (or existing stationary)	Y (TBC)
Ground	Recovery	Y (TBC)
Aircraft	Comms via plane	TBD, assumed Y
Aircraft	HAPS (or balloon experiment providers)	N

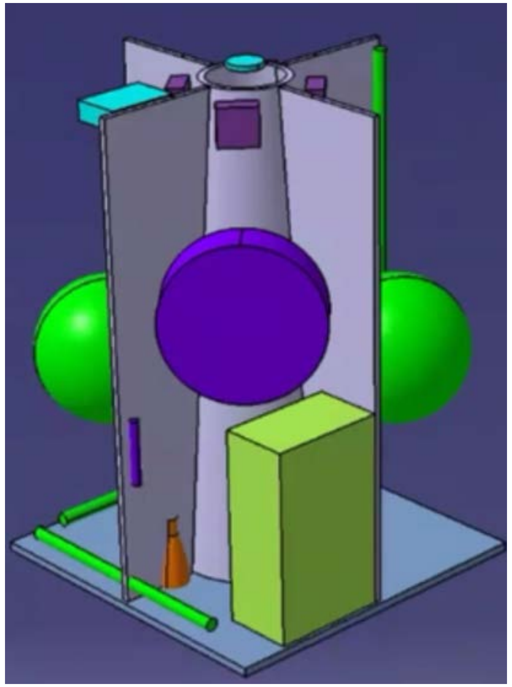
Mission system options



Topic	Survivable re-entry capsule
Ballistic coefficient	“Nominal” (no specific design efforts)
Structure	45deg conical with TPS
Power	Primary battery
DHS	Data recorder for P/L on platform Descent sequence activated by event (TBC)
TPS	Heritage
EDL	Case specific
Payload	IMU, GNSS

System options (platform)

Topic	Option 2: hybrid	Option 3: Reduced
Structure	Normal S/C representative + D4D hardware (TBC)	Normal S/C representative + D4D hardware (TBC)
Power	Body mounted solar array + secondary battery	Dummy units (TBC)
DHS	Normal	DCCU only
Communications	Rx and Tx to ground (no RF link to capsule)	No RF link (TBC) Possible dummy units
AOCS	Based on RCS + MTQ	Dummy units (TBC)
Thermal	Thermal control (TBC), Thermal protection DDCU	Dummy units, Thermal protection DDCU
Mechanisms	As required	None
Propulsion	Chemical, full system (thursters, tanks)	Dummy units
Payload	Survivable capsule + demisability payload only	Survivable capsule + demisability payload only
Time before re-entry	~4 days	None (direct re-entry at ejection from launcher)
Dimensions	~ 1.2 x 0.8 x 0.8 m	~ 1.2 x 0.8 x 0.8 m
Mass	~ 200 kg	~ 140 kg



The art of the possible

Large satellites / rocket bodies have been re-entering (and verified) for decades, but the procedures are based on extrapolation have limited representativeness

The need (dream/feasible) for DRACO to solve: Demonstrate the understanding of the process and physics on a large scale structure

- Follow pieces from final orbit down to ground (Understand the critical risk elements)

  -> Instrument specific parts till 60km in altitude.

- Instrument the platform (Understand the environment conditions where they matter)

  -> Instrument the structure till 60km in altitude.

- Determine the system level impact on equipment (Split-up the design requirements)

  -> Covered in the platform instrumentation.

Details science trade-off to be made as part of a phase A, but the “hybrid” and “reduced” options provide mass and volume allocations.

Next Steps

1. Design of a generic break-up recoding instrument (up to TRL6):
    - Establish baseline structure (with repeatability and accommodation in mind)
    - De-risk technologies (communication, DDCU)
    - Demonstrate expected sensor output

2. Define and establish the mission and system requirement (up to phase B1)
    - Elaborate on the CDF results to define the final science case configuration within mass / volume
    - In-depth mission analysis and break-up scenarios
    - Scaled thermal and data processing assessment for the specific mission


esa
DRACO
Demisable Satellite Mission