SURREY SATELLITE TECHNOLOGY LTD *Changing the economics of space*

SSTL Platform Evolution (Passivation)

Doc Num: ST# Pending

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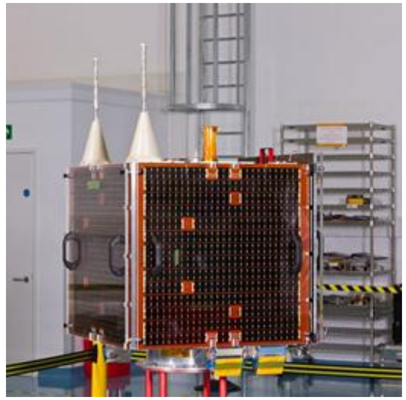
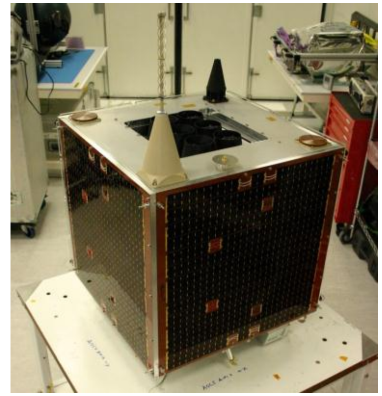
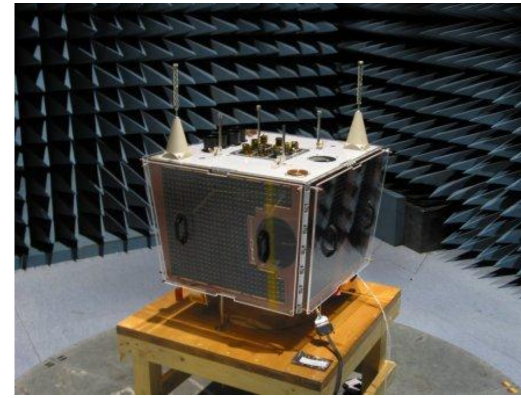
Introduction

- SSTL focuses mostly on the commercial LEO market.
- We have 3 main product lines that have been successfully used for more than 40 missions over the last ~30 years
- This situation, although "acceptable", needs addressing if SSTL is to remain competitive in the face of changing market needs.
- Current SSTL designs are optimised for:
  - Rapid/short build and test schedules
  - Batch building of large constellations (~15 Satellites currently in production)
  - Low cost
  - Flexibility and adaptability to a variety of mission payload/scenarios
- We need to apply the same philosophy to:
  - Debris mitigation
  - Disposal and passivation at End of Life

Current LEO Platforms

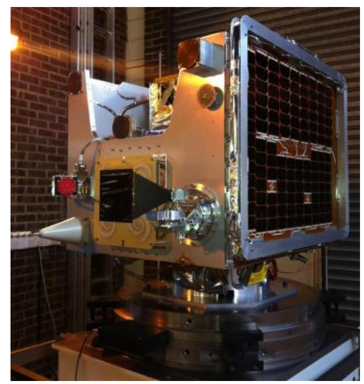
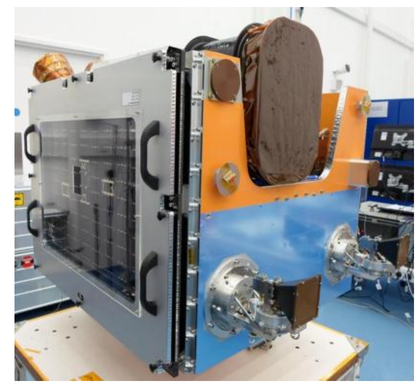
- SSTL-100

~100kg total mass
~15 kg payload
~40W OAP

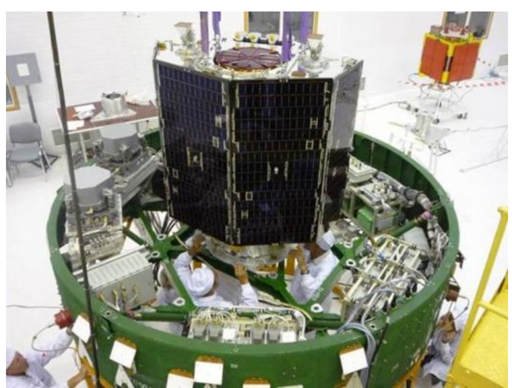
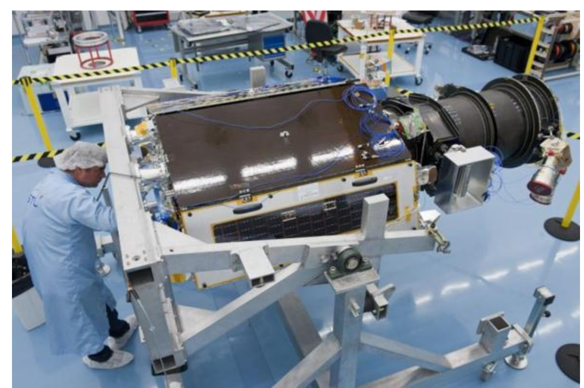
- SSTL-150

~150kg total mass
~50 kg payload
~60W OAP

- SSTL-300

~350kg total mass
~100 kg payload
~110W OAP

End of Life Issues

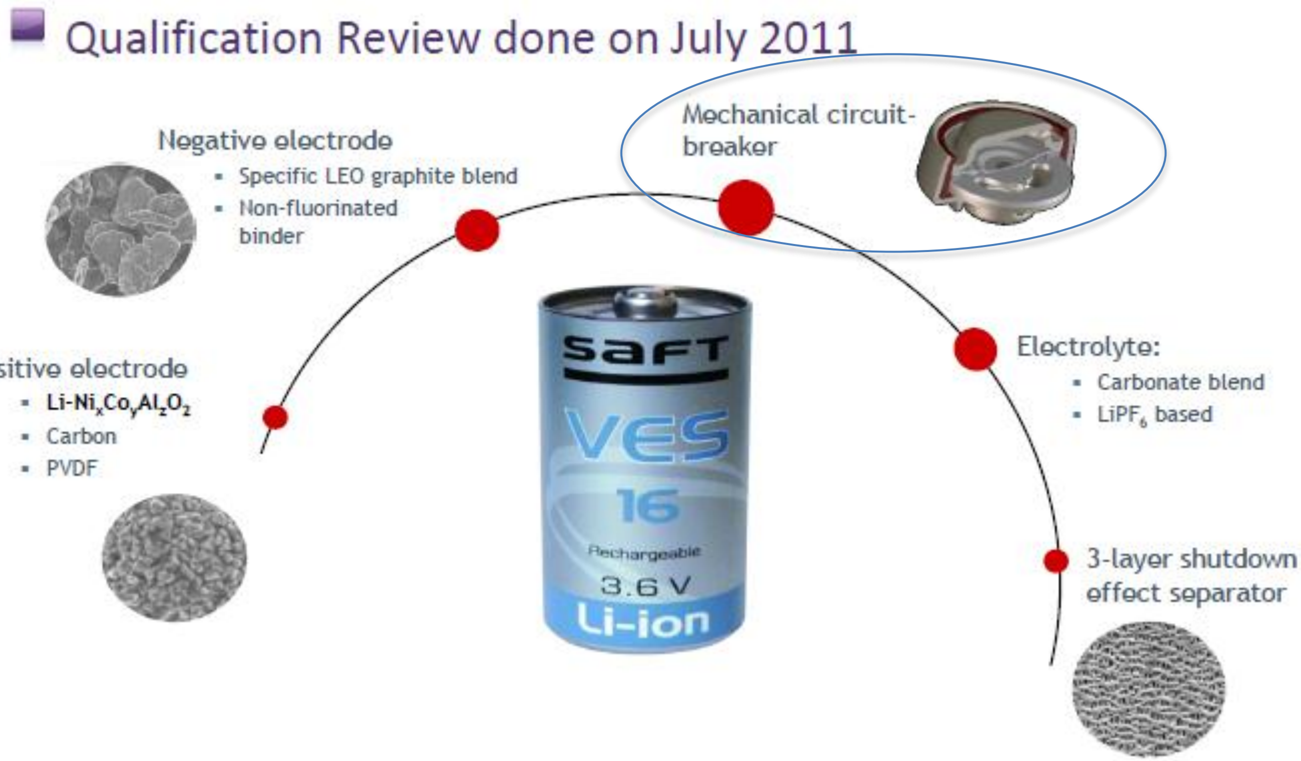
- Compliance with End-of-Life (EOL) requirements is becoming a major driver for new missions
  - Removal of potentially explosive elements
  - Passivation of energy sources on the spacecraft
  - Prevention of RF pollution
- UK Space Agency enforces 25 year compliance for all new launches under UK legal responsibility
  - Our aim: to satisfy the uncontrolled re-entry requirements (i.e. non-propulsive methods to accelerate orbit decay)
  - Drag sail (from Cranfield University) flying on TDS-1 and another SSTL small-sat scheduled for launch next year
  - OTB is flying and KazSTSAT is currently baselining an electro-dynamic tether (from USA)
- Other mission studies (e.g. CHEOPS, SAOCOM-CS) have baselined propulsive solution (hydrazine) for perigee drop at EOL, but this is a) expensive, and b) a major driver on the spacecraft configuration

End of Life Issues (Passivation)

- Currently SSTL spacecraft do not have passivated the power system. The power bus remaining active and the Rx permanently ON even if the spacecraft is nominally ‘dead’
- This presentation proposes a solutions for safely passivating the power system
- Key considerations are:
  1. Isolation of the battery from the spacecraft in a slow and controlled way. This affords time to detect the passivation process and resume normal operation without permanently degrading the battery should the process be initiated by accidental or malicious intent.
  2. Disconnect the power source from the power distribution system to
     - Prevent operation of any on board systems.
     - Avoid multiple failure scenario arising from reliance on parts to remain operational beyond their mission life and beyond their environmental limits (temperature and radiation)..
     - This will be a sequential process dependant on the successful completion of task 1.
  3. Gradual depletion of all stored energy in the battery cells.

End of Life Issues (Passivation)

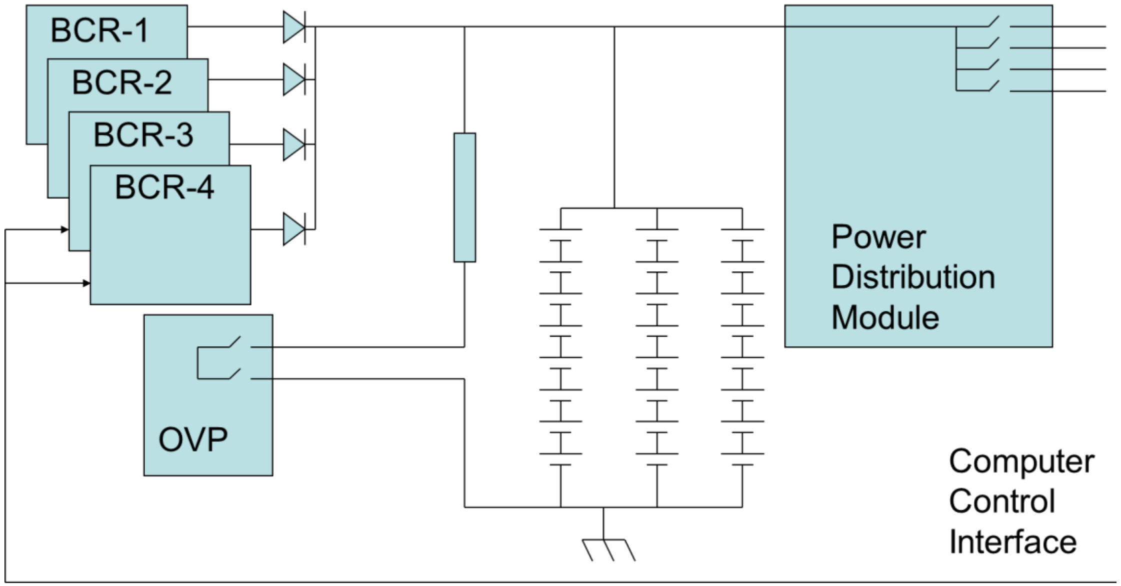
- As part of all SAFT small cell life qualification SAFT have demonstrated successful operation of the in-built cell overcharge protection Circuit Breaker at the end of life testing.
- Example of SAFT cell



End of Life Issues (Passivation)

- Following discussions with SAFT an agreement has been reached that no harm can come to cells or batteries at end of life if strings are isolated by activating the over-charge protection circuit breaker.
- SAFT batteries can be isolated from the bus by causing the circuit breaker to operate:
- Two system configurations have been investigated:
  - Whole battery overcharge
  - Individual string overcharging.

End of Life Issues (Passivation)

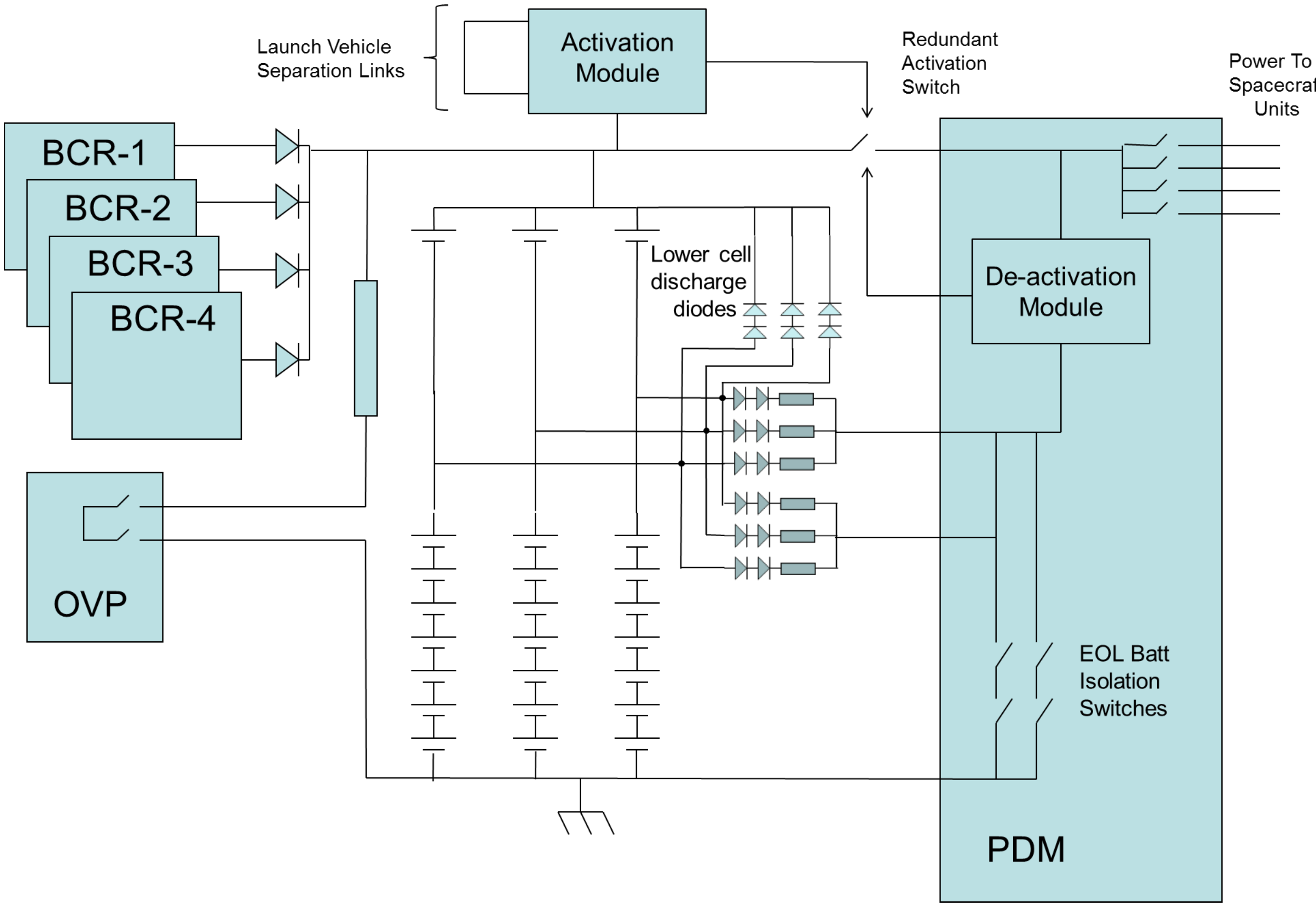


Whole Battery Overcharging:

- Individual BCR are diverted from MPPT to computer control.
- Output current is set to combine with an over-voltage protection load to achieve a bus voltage sufficient to operate pressure switch in battery (for example 8x4.6V/cell = 36.8V).
- In the process individual cells in each string will go open circuit leaving the battery disconnected.
- Negligible impact on present system configuration. Complyance with bus user voltage?

End of Life Issues (Passivation)

Individual String Overcharge: All SSTL LEO craft are launched OFF



End of Life Issues (Passivation)

Individual String Overcharge Procedure:

- At the end of the mission, action will be taken to remove any hazards associated with the propulsion system (not covered in this presentation).
- All nonessential loads are switched OFF.
- Series redundant EOL Battery Isolation switches are used to:
  - bias the top cell in each string (or 2 cells) to unbalance them and cause them to start overcharging.
  - Telemetry alarms are raised to tell ground operators that the sequence has begun.
  - Power is applied to the De-activation module.
- The bias current is selected such that it overcomes cell balancing currents but takes several orbits before the circuit breakers operate.
- As voltage on these cells increases, the voltage on the others drops (because total battery voltage is maintained at a constant maximum by the EoC system).

End of Life Issues (Passivation)

Individual String Overcharge Procedure:

- Eventually individual circuit breakers in each string will operate isolating the battery.
- In the absence of the top cells, the unbalance resistors will continue to discharge the lower cells.
- Each sunlight passage the power bus will be re-established but the battery will not be charged.
- During eclipses the “lower cell discharge diodes” will enable the bus to operate as a 7s battery.

End of Life Issues (Passivation)

Individual String Overcharge Procedure:

- In eclipse, the de-activation module monitors the 7s battery waiting for the voltage to fall below a pre-set EOD voltage threshold (for example 18V).
- On reaching 18V the de-activation module will disconnect the power bus from the power distribution system leaving the spacecraft depleted of fuel, electrical energy and all systems inactive. The remaining overcharged top cells will self discharge long before the end of the 25 year uncontrolled re-entry period
- No reliance on any parts functioning beyond the mission life time.
- Optional: The arrays could be clamped in the absence of a battery.

End of Life Summary

- There is varying compliance with the key debris mitigation requirements across the family of SSTL platforms
- Larger platforms (such as SSTL/300 DMC-3) are close to the boundary (~500kg) whereby re-entry risk is a general issue (not just prop tanks)
- SSTL power team have started collaborative work with SAFT to investigate battery passivation for all existing platforms
- New platform design (X50) will carry de-orbiting devices as standard equipment

Platform	Casualty risk compliance	Power system compliance	25 year compliance
SSTL-100	Yes	Not baselined	Not baselined (but compatible with sail or tether)
SSTL-150	Yes	Not baselined	Not baselined (but compatible with sail or tether)
SSTL-150 "Evolution" (e.g. as proposed for CHEOPS and SAOCOM-CS)	No (hydrazine tank)	Option in mission definition	Yes (hydrazine)
SSTL-300	Variable (function of propulsion system and payload)	Not baselined	Not baselined (but compatible with sail or tether)
X-50	Yes	Yes (TBC)	Yes (de-orbit device such as sail or tether).

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Thank You

Questions?