ALTRAN_D4D Building Blocks

Evolutions & Way Forward
BB 11: DEMISE Wheels

Reaction Wheels Assemblies are DEMISE - problematic for LSI LEO S/Cs

- **B11 investigated several options & proposed several D4D Initiatives**

- **Option 1: Mechanical Upgrade** (-11% inertia - Iso Volume – Iso Mass ?)
  => Take opportunity of RCD Initiative on **Monobloc Flywheels (68Nms)**
  **ALTRAN D4D Design (RSI68)** with flywheel material swap **Steel -> Aluminium**

- **Option 2: Electrical Upgrade** (-45% inertia – PWR x2 – Iso Mass?)
  => Take opportunity of RCD Initiative on **High-Torque Electronics (BBM, EQM)**
  **Mechanical downsizing (RSI45)** & **Increase of Speed and Torque Capabilities**
  **GOAL**: DEMISE COMPLIANCE and AOCS performance increased to COMPLIANCE

- **Option 3: Internal D4D techniques** (BBU: Ball Bearing Unit)
  **Internal Dismantlement, Core Material Swap, Re-use of Magnetic Wheels Technologies, Core Down-sizing** (Ball Bearing Unit Assembly)
Main DEMISE Investigations & Results: DEBRISK v2015: S/Ctest = S3 & S1 P/F

- BB11_Options 1&2 demonstrated MARGINAL COMPLIANCE (DEBRISK > 78km)
- BB11_Options 1&2 demonstrated NON-COMPLIANCE (DEBRISK <78km)
- Securisation needs ADDITIVE D4D Techniques
BB 11: DEMISE Wheels

Main DEMISE Investigations & Results:

Impact of Alternative Design: **Material** (Cu/Al/Ni) & **Size** (RSI 68/45/12) & **Diameter**

Conclusions:

- **DEMISE** impact: *Al > Cu > Ni* & **DEMISE vs Inertia Efficiency**: *Cu > Al > Ni*
- **Size impact**: BBU Demise **always PROBLEMATIC** for COMPLIANCE @ 65km Alt
- **Diameter Impact**: Larger Al Flywheels degrade RSI68 ballistic coefficient
BB 11: DEMISE Wheels

Main DEMISE Investigations & Results

- **RWC_Flywheel**: details Flywheel in RW **Coarse model** (Core attached to Flywheel)
- **RWC_Core**: detail Core element in RW **Coarse model** (Core demise after flywheel)
- **Core_Dismtl**: Core in **dismantlement scenario** Flywheel / Core
- **Flywheel_Dismtl**: Flywheel in **dismantlement scenario** Flywheel / Core

- **RWD_BBU**: details BBU block (with no dismantlement) in **Detailed model**
- **RWC_Core**: detail Core element (with no dismantlement) in **Coarse model**
- **BBU_Dismtl_Early**: Dismantlement of each BBU part after Housing demise
- **BBU_Dismtl_Late**: Dismantlement of each BBU part after Flywheel demise

- **BBU Dismantlement** is promising but raise **risk on flywheel** (Al->Cu?)
- **BBU parts EARLY dismantlement** sound the more promising but **more risky**
- **BB11_Options 3** demonstrated **CHALLENGING COMPLIANCE** (DEBRISK<78km)
BB 11: DEMISE Wheels

Main DEMISE Investigations & Results:

DEBRISK vs TAS-I & SCARAB (2015): +10% Ablated Mass / -10km release altitude
BB 11: DEMISE Wheels

Main RECOMMENDATIONS:

At RWA Equipment Level: Inspiration=NASA Goddard DEMISE Wheel
- Flywheel **spokes-brazed** design -> **Monobloc** (risk of several debris /uncontrolled release)
- RW Housing as **thin & DEMISE** as possible (few impact: 2km Alt / 1mm)
- Flywheel & **large apertures** spoke-like design: see RSI designs vs Simu models
- Drive Electronics: **External unit** instead of internal: see RCD(S1&S3) vs MOOG(S2)
- Internal **Dismantlement techniques** assessed as DEMISE-attractive but **risky** (case by case)
- Material swap (**Core parts** only) too risky for **BBU & tribology** aspects

RCD Position: **“Don’t change smtg working!!”** => Risk on 40 years flight heritage
=> **Main BB Lessons learnt:** Manage D4D Techniques @ S/C & P/F level instead

At S/C Architectural Level:
- RWA **External S/C** location (Airbus @ ESA D4D S/C activity)
- RWA on **Easy dismountable** panel (Thales @ ESA D4D S/C activity)
- RWA mounted on **Release I/Fs** SMA Mechanisms (ALTRAN BB10 CLEANSAT)
- RWA mounted on RWA (+Tank?) Architectural **DEMISE Block** (ALTRAN BB proposal)
**BB 11: DEMISE Wheels**

**Roadmap:**

- Assumed **NO CHANGE** since CLEANSAT BB11 closure

But **ALTRAN/RCD NDA ended early 2018**

**No MORE Feed-Back** from RCD

**At RCD Level:**

- EBBM EU units -> Status ?
- EQM EU Units -> Status ?
- Large Monobloc FlyWheel Redesign -> ?
- ESA TRP BBU demise improvement -> KO ?
- ESA CLEANSAT V2 Demise Wheels RFP ?

**At ALTRAN Level:**

- Support for Mechanical Large Flywheel **Redesign (BB11 REX)**
- Support for **Design for Demise Techniques** inside RWA
- Support for Demise **DRAMA/DEBRISK simulations** Coarse model (D4D trends)
- Support for Demise **Material DATABASE:** ALTRAN RESEARCH/ESTIMATE/Others ?
- Collaboration with HTG -> **SCARAB** Detailed model simulation of best technique ?
BB10 – Shape Memory Alloys Mechanisms

Shape Memory Alloys are used as Release devices activated by temperature
Application: S/C Controlled Dismantlement (asset for uncontrolled re-entry)

Step1 : D4D Release Devices Applications on S/C
  • Appendage Dismantlement, Structural Frames dismantlement
  • Panels Dismantlement, Modules Dismantlement P/F vs P/L?

Step2 : Release Mechanisms Investigations & Pre-Design
  • Frangibolts, Mechanisms, Cryofits, Pyro Cords : Pyro -> SMA?

Step3 : Shape Memory Alloys Development & Investigations
  • European Supply source of Frangibolt®-like TiNi alloys
  • High-Temperature SMA development + UHT SMA investigation

Step4 : SAT Thermal Characterization Analysis in Pre-Rentry >100km
  => Activation T° Triggering vs Safety Margin (Internal / External)
BB10–SMA Mechanisms

Outcomes: Baseline devices

1. **SMA Washers** (Struts, Screws, Clamp Band)
2. **SMA Inserts** (middle & end CFRP panel insert)
3. **SMA Sleeves** (Struts, P/L Booms)
4. **SMA Cutting Cords** (Tubular frames)
5. SMA Hinges (Fold Panel & Release at end)
**BB10–SMA Mechanisms**

**PROS & CONS : Concept 1 : SMA Washers**

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**Active & Passive** devices available  
Simple & Rustic / Testable / Reusable / Demise  
Triggering T° : <75-125°C (NT) / <100-250°C (HT)  
Safety Margin T° : 35°C (NT) / 50°C (HT)  
TRL: NT=6 / HT=5 -> **ESA-OHB dismantlement Test @ DLR !!**

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**Screw Tension @ 50% Screw Rupture**  
M6 Design => M5 Tension (screw striction)  
CTE: (NT=11->Ti) (HT=17-> SS & Ti?)  
OverLength => 4D (washer & screw)  
Density: 6-7 (Mass x4 vs Standard I/Fs)
BB10–SMA Mechanisms

**PROS & CONS : Concept 2 : SMA Inserts :** Thread parts enlaced & released with SMA actuator

<table>
<thead>
<tr>
<th>Same SMA Materials &amp; supplier / Same PROS</th>
<th>More Complex: Tribology &amp; Mechanisms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dismountable / Testable / Reusable / Demise</td>
<td>TRL: 3 -&gt; 4 (end 2018) -&gt; 5 (OHB tests 2019 ?)</td>
</tr>
<tr>
<td>ISO-Screw I/F definition =&gt; Length/Diameter/Material</td>
<td>Development / Validation: Higher NRCost</td>
</tr>
<tr>
<td>ISO-Thread I/F (TBC) =&gt; Tension/Material/Torque</td>
<td>More Parts: Iso – RCost ?</td>
</tr>
<tr>
<td>FEW SMA material =&gt; Not used in I/F structural path</td>
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<tr>
<td>Compact &amp; Light =&gt; 50% mass saving vs Frangibolts</td>
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**Concepts Evolution :** (2016->2018)

**Lessons Learnt :**

- SMA resistance **Cold/Hot 1:4**
- => **No Cold SMA** for structural purpose (screw tension axial/radial need large amount of SMA)
- Metallic **Elastic Return** after 40yrs is erratic
- **Shock Release** Helps !! (to be adapted for SMA)
- Compact **Cylinder Panels Inserts fits Everywhere**

**Device Mounting : Rear / Front (1.2.3.)**

**Device Tension :**
1. Spring Wire / 2. Strip Spring
3. Blocking part push released under screw/thread radial tension

**Device Actuator :**
1. SMA Springs / 2. Small Frangibolt / 3. Belleville SMA Washers
BB10–SMA Mechanisms

**ROADMAP:**

=> **Almost NO CHANGE** since CLEANSAT BB10 closure

**NOTA:** **ALTRAN/NIMESIS** partnership is now more than 4 Yrs Old !!

At **NIMESIS** Level:

- CNES R&T (large SMA-HT parts engineering) => **Starting right now !!**
- Concept 1 Design authority: **SMA Washers**
- SMA Mechanical Characterization
- SMA Alloy Process Engineering / Development / Production

At **ALTRAN** Level:

- Concept 2 Design authority: **SMA Inserts** / Other D4D mechanisms
- Impacts on Satellite architecture & Design for Demise
- Space Qualification Documentation (Test plan / Test reports / File Justification)
- Support for Product & Qualification Assurance / Material & Process compliance

At **PARTNER(s) Level:** => **TBD** (every partner & customers are WELCOME !!)

- Mechanism Assembly / Integration / Environmental Tests (**Qualification** Phase)
- Mechanism Assembly / Integration / Environmental Tests (**Mass Production** Phase)

PS: Thanks to OHB Team for their Intention Letter @ ESA ITI initiative 2017
**SPIN-OFF : Reentry Simulation**

**TOPIC :** S/C Thermal Characterisation  
**ALTRAN_ESATAN S/W on S/C Thermal Models**  
Correlated Model (post CDR & TVAC thermal balance)  
$\Rightarrow$ Full Representativity of Th couplings / Accuracy Int & Ext

**APPROACH :** S/W Reentry Trajectography  
DEBRISK–DRAMA Trajectory (no attitude) +  
Aerothermal Flux calculation = $f$ (alt , time)  
*(Free molecular – Non Tumbling Box)*

**Assumed Non–Tumbling** (REALISTIC: SAW trail drag)  
$\Rightarrow$ Considered as a Worst Case ($T$ Gradient)

**CONCLUSION:**  
$\Rightarrow$ Worst Hot Case : Front MLI Faces : 250–300°C  
$\Rightarrow$ Worst Cold Case : Rear Faces : <0°C
**SPIN-OFF : Reentry Simulation**

**TOPIC :** S/C Dynamic Characterisation

**ALTRAN_NASTRAN** S/W on S/C CAD model

Full Geometrical Correlated Model (post CDR CAD design)

⇒ Full Representative of external shapes & Accurate MCI (inertias)

⇒ No remodelisation

**APPROACH :** S/W Reentry Trajectography

DEBRISK–DRAMA Trajectory (no attitude) + Dynamic Characterisation (NASTRAN)

Flux direction & intensity: MSISE–00 assumption = f (alt, time)

⇒ 3 axis Torque & Force NASTRAN characterisation per Azimut/Elevation

(Only front faces exposed to Flux produces Torque ⇒ shadowing effect)

**NEXT STEP :** (Reuse of 3D LAUNCH/ ORBIT & 3D AOCS simulator → 6D)

Simulation S/W: Torques/Forces during Reentry step by step

⇒ Attitude & Dynamic rate on Reentry Trajectory ⇒ INPUT for ESATAN

⇒ Downtrack/CrossTrack impact vs initial Trajectory ⇒ Google Earth Movie

**CONCLUSION: (Expected End 2018)**

Dynamic & Attitude Determination in high Atmospheric perturbation

⇒ Uncontrolled Reentry : 3 Axes Dynamic Behaviour (→ ESATAN)

⇒ Controlled Reentry : Attitude Control (or NOT) in low perigee
SPIN-OFF: ALTRAN / CLEANSPACE

ALTRAN RESEARCH Cannes Evolution => Launcher Elements Debris
ALTRAN Cannes_ “SYLDA Not Released” _CNES_DLA (2016–2017)
⇒ Petals, Expansible Gantry, Lift, Robotic Arm

ALTRAN RESEARCH Cannes_ LAUNCHER Stage Debris Mitigations (2018)

ST1R: 1st Stage: Suborbital Reentry /Recovery / Reuse
⇒ Air Capture: A.C / Drone A/S Air Capture
⇒ CATAPULT Launch (SPIN LAUNCH –like)

ST2R: 2nd Stage: Orbital Reentry/Recovery / Reuse
⇒ Reentry Kits: Inflatable Cone / Inflatable Wings
⇒ Shuttle Transfo: Folded Wings / Fairing / SSTO

ST3R: 3rd Stage: NO Reentry, Reuse in Orbit
⇒ ADR, Servicing, Maintenance,
⇒ Fuel Deposit, Space Tug (Cargo,Crew)
⇒ Assembly, Built in Space, Modular S/C (SATLETs)
SPIN-OFF: ALTRAN / CLEANSPACE

TOPIC: EXTENSION of “CLEANSPACE” Spin Off @ ALTRAN = “GREENSPACE Community”?

ALTRAN RESEARCH Toulouse _ CIR “SPACE CLEANER “
ADR Research – Small Debris / Large Quantity / High Rate Contactless Capture
⇒ Main FOCUS on multiple RDV capability & optimisation in debris swarm
⇒ GTOC 9– Like initiative & Exercise

ALTRAN Aerospace Toulouse_ Life Cycle Assessment Expertise
Environmental Impact of Aerospace Production/Operations*

ALTRAN Aerospace Cannes _ SPACE SAFETY Expertise
Space Industry Material/Process Database –> REACH compliance

ALTRAN RESEARCH Toulouse _ CIR NACIN
Airliner Engine Exhaust section optimised by SMA actuators
⇒ SMA FEM simulation Codes for behaviour prediction

ALTRAN RESEARCH Aix _ CIR INSIDE
3DPrinted – Heat exchanger development –> Industry 4.0 Topics:
Topological design optimised for Thermal/Mechanical Efficiency
TEAM Presentation

ALTRAN_FR Key Personnel:

**Stephane Heinrich** is a senior ALTRAN consultant with experience working for customers on-site such as Thales, Airbus, Safran Groups. With almost 25 years experience, he mostly worked on space and ESA projects (GOMOS - IASI instruments, ATV avionics chain, PLANCK, Sentinel-3 satellites).

He has a clear expertise in **avionics and propulsion equipments**. He was trained by TAS-F dependability and safety department and IAASS in ALTEC_I. He is an IAASS professional fellow attending most **space safety** conferences.

He is currently leading an **ALTRAN Research** Team working on **Space Debris** topics: “**MMOD** : Satellite Robustness to Micro-Meteoroid and Orbital Debris” “**ODAR** : Orbital Debris Atmospheric Reentry” for satellite & launchers “**MMOD L/V** : Mitigation Measures for Orbital Debris of Launch Vehicles”

**Arthur HUMBERT** is a **Young Graduate Trainee** from ESTACA-ISAE. He is involved as internship at ALTRAN Research in innovative studies relative to Launchers technologies and performance. He is the former leader of **SPACE ODYSSEY** (rockets building / testing).