The AEOLUS Mission
- In Orbit Commissioning and Verification

ADM-Aeolus CAL/VAL Workshop, ESRIN

P McGoldrick, J Brewster, J Marshall, F Fabre

Airbus Defence and Space, UK and France
12th February 2015
ADM-Aeolus Overview

Mission Objectives
• To measure global wind profiles up to an altitude of 30km

Mission Details
• Duration: 3 years plus 3 month commissioning phase

Mission Orbit
• Sun-synchronous, dusk/dawn orbit
• Inclination 97°
• Altitude: 408km

Configuration
• Total dry mass of 1090kg comprising:
  • Platform 614kg (plus 264kg propellant)
  • Payload 476kg
• Dimensions (launch configuration)
  • height 4.37m, length 2.08m, width 2.00m
Phase E1 Activities

- Phase E1 consists of the Launch campaign and support to the LEOP, commissioning and instrument calibration phases
- The **IOC&V Plan (AE.PL.ASU.SY.026 currently issue 5)** covers the commissioning of the satellite, switch on and initial verification of the instrument, and instrument product characterisation up to Level 1b.
- ESA will control the satellite in accordance with the FOM and IOC&V Plan and Procedures.
- ESA will operate the processor to generate Level 1b, 2a, and 2b products
- Astrium will provide satellite expert support on site for initial operations and will be on-call thereafter
- Astrium will validate the satellite performance based on the telemetry and L1b products supplied by ESA
- Phase E1 concludes with an In-Orbit Commissioning Review at L + 3 months and closure of resulting actions
Phase E1 Activities

IOC&V Plan

Launch & Early Orbit Phase

Platform Commissioning and Instrument Switch-on

Initial Instrument Characterisation & Calibration Tasks

Product Validation

Phase E2 Preparation

Launch Campaign

Airbus

Launch campaign management

Expert support of platform operations:
- LECP Auto sequence
- Nominal Mode
- Orbital stabilisation

Platform Commissioning
- ICS Control Stabilisation
- Support of instrument switch on
- Beam position drift
- Instrument PLH parameter adjustment
- Instrument initial on-board calibration
- Demonstration of L1 processing

On-call platform support (<5 working days)
- Periodic instrument calibration and PLH parameter adjustment
- Characterisation of Ground Echoes
- Verification of on-board terrain model
- Attitude error calibration
- Verification of HSE
- In-orbit Incentive Demonstration
  - Measurement of Ground Velocity in Measurement Altitude
  - Measurement of Pseudo Wind Velocity in E2ECat Altitude

Preparation of an IOCR package [D-SA14]

Definition and upload of nominal settings for platform and instrument calibration cycles

In-orbit Commissioning Review (IOCR)

Agency

Flight operations preparation

- Platform operations
- Ground segment support

- Platform and Instrument operations
- Orbit maintenance
- TM analysis facilities
- Ground segment support

- Platform and Instrument operations
- Orbit maintenance
- Characterisation of optical transmission in Mie and Rayleigh Channels Using L2a / L2b processing
- Provision of measured temperature profile with a random error better than 2 degrees.

- Verification of L0, L1b, L2a, L2b processing performance
- Initial assessment of error budgets in L1 / L2 products
- Interpretation of correlative measurements
- Initial assimilation experiments & impact analysis
- Refinement of long-term validation tasks
- Identification of updates to L1, L2 algorithms and code
- Support of specific CalVal projects, correlative campaigns
### IOCV Platform Tests

<table>
<thead>
<tr>
<th>No</th>
<th>Test</th>
<th>Description</th>
<th>No of Orbits for data collection</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>LEOP sequence</td>
<td>Execution of LEOP and transition to IAM. Status check</td>
<td></td>
<td>Auto sequence initiated via Launcher separation</td>
</tr>
<tr>
<td>P2</td>
<td>S-Band Communications</td>
<td>TM review to confirm normal behaviour. S-Band downlink and uplink</td>
<td>2-3</td>
<td>FCP_A_005, FCP_S_025, FCP_S_010,020, FCP_S_080</td>
</tr>
<tr>
<td>P3</td>
<td>X-Band MMU switch on</td>
<td>Data downlink process checked via X band.</td>
<td>1</td>
<td>FCP_A_005, FCP_S_030 Plan X Band and S Band link coverage together</td>
</tr>
<tr>
<td>P4</td>
<td>AOCS commissioning.</td>
<td>Phase 1 check GPS, AST, RWU performance. OBT vs GPS Time</td>
<td>1</td>
<td>FCP_A_005 Switching from IAM to Normal Measurement attitude.</td>
</tr>
</tbody>
</table>
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<tr>
<td>P5</td>
<td>Switching to On Board Schedule</td>
<td>X band downlink timing via Orbit Position Scheduling</td>
<td></td>
<td>FCP_S_385</td>
</tr>
<tr>
<td>P6</td>
<td>Orbit acquisition, AOCS E2E slew.</td>
<td>OLVLH to NADIR and back. Transition to NM.</td>
<td>1</td>
<td>FCP_S_760 FCP_A_025</td>
</tr>
<tr>
<td>P7</td>
<td>RCS calibration</td>
<td>In plane and Out of plane manoeuvres</td>
<td></td>
<td>FCP_S_035,36 FCP_S_040</td>
</tr>
<tr>
<td>P8</td>
<td>S-Band TTC tests</td>
<td>Check lock status, Bit Error rates, ranging</td>
<td></td>
<td>FCP_S_020</td>
</tr>
<tr>
<td>P9</td>
<td>ICS Start up</td>
<td>ICS off, monitor cavity pressure decay. ICS on, set pressure range</td>
<td>1</td>
<td>FCP_ICS_040</td>
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## IOCV System Tests

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<tr>
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<th>Number of Mie / Rayleigh observations processed</th>
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<tbody>
<tr>
<td>S1</td>
<td>GPS Commissioning</td>
<td>Calibration of on-board geo-location with ESOC FD orbit</td>
<td>5 (TBC)</td>
<td>N/A</td>
<td>Check for VTEC bias on GPS</td>
</tr>
<tr>
<td>S2</td>
<td>Aladin Check-out and Calibration</td>
<td>Switch on instrument and calibrate parameters</td>
<td>30 including overheads</td>
<td>320 (for calibration)</td>
<td>Calibration (NADIR) attitude needed for IRC, RRC</td>
</tr>
<tr>
<td>S3</td>
<td>Attitude error / HBE characterisation</td>
<td>Adjust attitude biases until ground echoes are within altitude criteria of L1B Processor. Collect sufficient echoes for HBE fit</td>
<td>4 (clear sky)</td>
<td>100 with Mie and Rayleigh ground returns</td>
<td>Potential large schedule overhead due to need for clear sky. See flowchart slide</td>
</tr>
<tr>
<td>S4</td>
<td>Ground velocity in Measurement Attitude</td>
<td>Measure statistical properties of velocities of ground bin. HBE coefficients used.</td>
<td>4 (clear sky)</td>
<td>100 with Mie and Rayleigh ground returns</td>
<td>Velocity offset = 0 Schedule overhead due to need for clear sky Rehearsal for Functional Performance Demonstration</td>
</tr>
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<tr>
<td>S5</td>
<td>Wind velocity in Calibration Attitude</td>
<td>Measure wind speeds at all altitudes while satellite is in Calibration Attitude</td>
<td>1/3 orbit (30 minutes)</td>
<td>64</td>
<td>Rehearsal for Measurement Performance Demonstration</td>
</tr>
<tr>
<td>S6</td>
<td>Functional Performance Demonstration</td>
<td>Ground wind speed random error in Measurement Attitude</td>
<td>4 per velocity offset (clear sky)</td>
<td>100 with Mie and Rayleigh ground returns per velocity offset</td>
<td>Velocity offsets 0m/s, +100m/s, -100m/s generated by attitude biasing. Up to 7 days allocated for data collection</td>
</tr>
<tr>
<td>S7</td>
<td>Measurement Performance Demonstration</td>
<td>Measure wind speeds at all altitudes while satellite is in Calibration Attitude</td>
<td>1/3 (30 minutes) per velocity offset</td>
<td>64 per velocity offset</td>
<td>Velocity offsets 0m/s, +100m/s, -100m/s generated by attitude biasing.</td>
</tr>
</tbody>
</table>
End to End Attitude Adjustment

Attitude error optimisation prior to HBE characterisation

- Set constant bin height of 250m and switch off on-board terrain model
- Set standard bin heights and switch on on-board terrain model
- Use Level 1B Lite to change apparent attitude of the satellite in roll

5.1 Perform VTEC Calibration

5.1 Acquire data in Measurement Attitude. Confirm ground echoes.

5.2 Acquire data in Measurement Attitude. Check number of ground echoes.

5.2.1 Update AST alignment matrix

5.2.1 Pointing characterisation and correction in roll to improve yield of ground returns

5.3 Acquire and accumulate data in Measurement Attitude.
## Instrument Switch on

<table>
<thead>
<tr>
<th>Aladin Test / Calibration</th>
<th>Detail</th>
</tr>
</thead>
</table>
| **Receiver Test**         | 1. Dark Current Calibration (DCC) (LBWU Mode, laser off)  
2. Receiver chain end-to-end test to L1b (MEAS Mode, laser off, modified dt3) |
| **Laser switch on**       | 1. Nominal energy  
2. Repeat DCC |
## Verification after Instrument Switch on

<table>
<thead>
<tr>
<th>Aladin Calibration</th>
<th>Detail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instrument Spectral Registration (ISR)</td>
<td>Thermal tuning of Rayleigh Spectrometer to bring transmit frequency to centre of Rayleigh receiver.</td>
</tr>
<tr>
<td>Instrument Auto Test (IAT)</td>
<td>Verification of Mie and Rayleigh receiver spectral transfer functions</td>
</tr>
<tr>
<td>Alignment check</td>
<td>Confirm spectrometer alignment (fringe form and relative location of the Rayleigh spots)</td>
</tr>
</tbody>
</table>
## Weekly Calibration

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<tr>
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<th>Detail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instrument Defocus Characterisation (IDC)</td>
<td>Thermal focusing of Rayleigh images</td>
</tr>
<tr>
<td>Instrument Response Calibration (IRC)</td>
<td>Mie and Rayleigh receiver response for 40 frequency (velocity) steps while in nadir attitude. Confirm Rayleigh intercept repeatability.</td>
</tr>
</tbody>
</table>
## Initial Instrument Characterisation

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<th>Detail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verification of Ground Echoes</td>
<td>Check ground echoes from different terrains and verify on-board terrain model. Calibrate systematic component of Absolute Pointing Error (APE) in roll</td>
</tr>
<tr>
<td>Harmonic Bias Estimation</td>
<td>Verify use of HBE and calibrate systematic component of Absolute Pointing Error (APE) in pitch</td>
</tr>
</tbody>
</table>
Reference documentation

- Instrument verification plan
  AE.PL.ASF.AL.00011 iss 5 rev 2
- Noise in darkness measurement
  AE.RP.ASF.AL.00086 iss 1
- Aladin wind performance budget
  AE.TN.ASF.AL.00086 iss 3
- Characterisation data base
  AE.TN.ASF.AL.00235 iss 4 rev 1
- IOCV Plan
  AE.PL.ASU.SY.00026 iss 5
- Mission and Performance Budgets
  AE.RP.ASU.SY.0128 iss 6
- Master algorithm document
  AE.SW.ASU.GS.023 iss 7 (plus red line input)
- Aeolus Flight Operations Manual
  AE.MA.ASU.SY.003 iss 3.5 Volume 1 (Vol 1-8)

Prime Team Members

- John Brewster Systems and Performance
- Mark Hannington Operations
- Jon Marshall Data Processing
- Andrew Davies Functional Verification
Thank you for you for listening

...any questions?