ESPA Satellite Dispenser for ORBCOMM Generation 2

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ESPA Satellite Dispenser for OG2 Constellation

• ORBCOMM Low Earth Orbit constellation
  – Global asset monitoring and messaging services
  – Original constellation: 35 satellites launched in late 1990s.
  – Generation 2 (OG2) satellites upgrade and expand network

• OG2 satellites manufactured by Sierra Nevada Corp (SNC) with payload from Boeing Argon ST
  – Eighteen satellites
  – More data capacity, more robust messaging services

• Two launches on SpaceX Falcon 9 v1.1
  – Environmental assessments: acoustics, shock, quasi-static loads

• Satellite dispenser built on ESPA rings
  – First constellation using ESPA multi-payload adapter
  – Other constellations are considering similar ESPA configurations, e.g., COSMIC2, PlanetIQ
EELV Secondary Payload Adapter

• ESPA ring family originated in late ‘90s to provide capability to Air Force for launching small experimental payloads
  – CSA Engineering designed ring under AFRL/Space Vehicles SBIR contract with funding and technical guidance from DoD Space Test Program

• Prototype designed for Atlas V and Delta IV
  – Flight qualified as secondary payload adapter for EELV Medium
    • 15,000-lb primary satellite
    • Six “ports” with 15” interface provide mounts for six 400-lb secondaries
  – Installed at Standard Interface, 62” bolt circle at top of upper stage

• First flight of ESPA in March 2007 on STP-1 mission

• ESPA is modular, standard component of space launch infrastructure
  – Provides proven route to orbit
Primary design objective: *Minimize impact on primary*

- Ring height originally 24 inches so only small fairing volume taken away from primary
- Structure is stiff in all directions: minimal impact to primary
- SoftRide vibration isolation systems available to reduce environmental loads and provide de-coupling of small sat from primary satellite
ESPA as Constellation Satellite Dispenser

- Constellation launches first considered in 2002
- ULA sponsored study by SpaceDev and CSA in 2007
- ORBCOMM feasibility study for ESPA dispenser on Falcon 9 in 2012
  - Stacking ESPA rings as multi-satellite dispenser avoids custom adapter and minimizes development effort
  - ESPA Grande selected to accommodate OG2 satellite size (not weight)

2002 constellation concept
OG2 Satellites

- OG2 augments network with more subscriber transmitters and receivers, with higher data rate capabilities
- Satellites manufactured by industry team led by SNC
  - Peak solar array power at End of Life ~670W
  - 3-axis-stabilized nadir pointing, yaw-axis sun-tracking ACS system
  - 34AHr Li-Ion batteries
  - Weight 392 lb (178 kg)
- Fully reprogrammable software defined radio provided by Boeing’s Argon ST subsidiary
  - Enhanced messaging capabilities, increased capacity, Automatic Identification Systems (AIS) service
OG2 Dispenser Configuration

Dispenser configuration for OG2 Mission 1

- Two ESPA rings, SoftRide, custom flat plate adapters, electrical harnesses for power, data, separation signals
OG2 Launch Environment Mitigation

- ESPA Dispenser employs vibration isolation to mitigate structure-borne vibration and shock
- Moog CSA SoftRide whole-spacecraft vibration isolation
  - SoftRide has flown on 28 missions to date, including Falcon 9 CRS-1 Mission in October 2012 with prototype OG2 spacecraft
    - CRS-1 telemetry confirmed hardware functionality
    - Isolation of entire launch stack or assembly of multiple satellites is feasible
- Analysis determined OG2 stack isolation preferable to isolating each spacecraft
- Coupled loads analysis has demonstrated performance
ESPA Grande

- Developed as ESPA variant to provide capacity for larger and heavier secondary payloads compared to standard ESPA
  - Original sizing from 2004 NASA engineering study for proposed New Millennium mission
  - Mission was not funded, but CSA completed design under NASA Ames SBIR contract in 2007
- OG2 ESPA has four 24” ports on 42”-tall ring
  - ESPA 4-24-42
- First ESPA 4-24-42 shipped August 5
ESPA 24-inch Port Capability

• 24” bolt circle enables secondary payloads to 700 lbs (318 kg)
  – 24” diameter is consistent with other adapters including CubeStack wafer adapter for CubeSats
  – Separation systems available from PSC, SNC, RUAG

• ESPA Grande secondary capability compared to standard “ESPA-class” 15” interface
OG2 Mounting on ESPA Grande

- ESPA Grande used because of OG2 volume, not weight
- Spacecraft mounted on interface plate to adapt to ESPA 24” port with 36 fasteners
  - Standard fastener 1/4-28, but size increased to 5/16-24 to accommodate 15g in all axes (OG2 satellite qual level)
- To minimize launch-site integration time, adapter integrated to spacecraft prior to shipment
  - Satellite shipping containers accommodate ESPA interface plates
Electrical Harness

- Dispenser electrical harness distributes power, data, and separation signals from launch vehicle to OG2 satellites
  - Connector interfaces, cable capacity, mechanical routing coordinated with SpaceX and SNC
  - Brackets for connector bulkheads, and routing of harness across ESPAs and across SoftRide system

- Assembly per NASA-STD-8739.4

- 8-satellite stack with simple mechanical and electrical interfaces to the LV
Falcon 9 v1.1 Launch Environment

- F9 Payload User’s Guide flight environments reviewed with SpaceX in preparation for ESPA Dispenser CDR
  - Critical loading environments: quasi-static loads, acoustics, shock
- Analyses demonstrated all Dispenser elements except SoftRide isolators have positive margins due to all flight events with no-test safety factors
  - OG2 SoftRide flexures were subjected to qualification program, and all SoftRide flight parts have been acceptance tested
- Actual loads, accelerations, deflections computed with coupled loads analysis
  - Dispenser modeled in detail including SoftRide damping matrix
SoftRide Whole-Spacecraft Vibration Isolation

• Mechanical isolation acts as low-pass filter to attenuate vibration energy above isolation frequencies
• Whole-spacecraft isolation typically implemented to mitigate one or more known launch load events
  – e.g. solid-rocket motor resonant burn, random vibration MPE
  – Requires linear system for all load events, including tensile preloads from 2g to compression loads of 6g or more
  – SoftRide employs all-metallic load path with parallel viscoelastic damping
• Flight heritage on 9 vehicles ranging from Minotaur to Delta IV Heavy
  – SoftRide must be included in Mission coupled loads analyses
• Falcon 9 v1.1 new vehicle and design environments still being developed
  – SoftRide is risk reduction due uncertainty in structure-borne loads
Dispenser Strength and Dynamics

- Strength analysis performed in NASTRAN with model of payload stack coupled to Falcon 9 Payload Attach Fitting
  - SoftRide modeled with NASTRAN Direct Matrix Input at a Grid (DMIG)
  - Satellites with interface adapters included as Craig-Bampton models
- SoftRide analysis showed ample margins on strength and minimum mode frequencies with temperature dependent damping modeled over flight temperature range
  - “Rocking” at 10 Hz
  - “Bounce” at 25 Hz
Vibro-acoustic Environment

- Model created and analysis performed with VA-One
  - Payload stack subjected to max predicted acoustic environment
- Model predicted payload stack vibration at spacecraft interface and spacecraft deck
  - Predictions compared to acceptance requirements
  - OG2 spacecraft have random vibration limit specification
- Analysis showed acceptable response levels
  - Spacecraft/Dispenser interface predictions for vibration are compliant to interface requirements
  - Payload and equipment deck predictions comply with acceptance requirements

Falcon 9 v1.1 Payload Fairing Acoustic Environment Requirement; 139.6 dB OASPL
Shock Environment

- F9 Payload User’s Guide shock environment at Dispenser interface to PAF
  - OG2 spacecraft have Dispenser interface shock requirement
- Shock attenuation through Dispenser estimated with distance attenuation factors and experience-based joint attenuation factors, combined with test-based SoftRide shock attenuation
  - Predicted shock due to launch vehicle induced events is compliant to Dispenser/Spacecraft interface requirement

Falcon 9 Shock Environment, Launch Vehicle Side of 62” Interface
Integration

• Integration activities at launch site on very tight schedule
  – Facilitated by modular ESPA features and eight identical satellites

• Integration activities prior to shipment
  – Mating of satellites to Flat Plate Adapters at SNC in Louisville
  – Integration of harnesses to ESPAs at Moog CSA in Mountain View

• Ground support equipment and Interface Control Documents for assembly of Integrated Payload Stack
Mission 2

- Falcon 9 to launch remaining spacecraft of ORBCOMM Generation 2 constellation
  - Planned for 2014
- Satellite Dispenser based on Mission 1 Dispenser with capability added for at least one more spacecraft
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