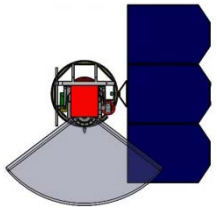
PACE 2012

Launch Vehicles

14 – 18 May, 2012

“We can lick gravity but sometimes the paperwork is overwhelming”
Werner von Braun”

PACE 2012 Launch Vehicle Assumptions / Information



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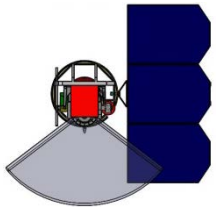
- **Requirements: – Near-noon sun-synchronous polar, 11 AM to 1 PM equatorial crossing (noon is optimal), ~700 km**
- **Launch Date: October 1, 2019**
- **Mission Lifetime – 3 Years required / 5 Years desired**
- **Mass estimate : ~ 1,000 kg (Plus 30% = ~1,300 kg)**
- **Launch Site: Vandenberg AFB, California / Kodiak Island, AK (Alaska Space Port)**
- **Launch Vehicles and Designations:**
- **OSC Antares 120**
- **Space X Falcon 9,**
- **Lockheed (LMLV) Athena II**
- **OSC Minotaur IV**
- **See Supplied NASA (LSP) Launch Services Program: Launch Vehicle Performance for Assumptions for Payload**
- **Fairing, Payload Attach fitting and Spacecraft Separation System**
- **Back Up Information Provided:**
- **Launch Vehicle (NASA Launch Services Program (LSP II) Performance and Assumptions**
- **Definition of maximum Payload: Separated S/C Mass (PAF Mass on Launch Vehicle Side)**
- **Launch Vehicle Injection Errors: Orbit Injection Accuracies**
- **Launch Vehicle Tipoff and Roll Rate Capacities:**
- **Launch Vehicle Mission Time Line (Lift Off to S/C Separation) if available.**
- **Interfaces:**
- **Fairings: Atlas V (500) 5 m**
- **PAF Payload Attach Fittings (Specifications):**
- **Launch Vehicle PAF Center of Gravity (CG Maximums):**
- **Environments:**
- **Load Limits:**
- **Mission Unique Equipment/Services:**

OSC Antares 120 (3.9m/3.45m OD/ID) Launch Vehicle



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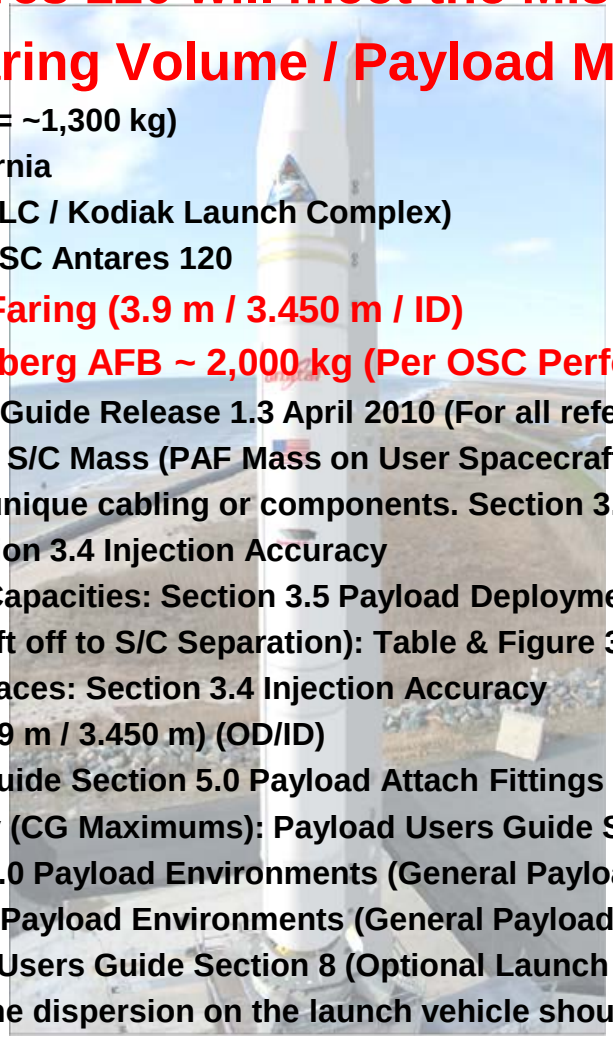
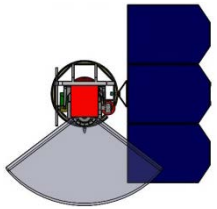
- **Note: OSC Antares 120 will meet the Mission requirements:**

Faring Volume / Payload Mass



- Mass estimate : ~ 1,000 kg (Plus 30% = ~1,300 kg)
- Launch Site: Vandenberg AFB, California
- Launch Site: Kodiak Island, Alaska (KLC / Kodiak Launch Complex)
- Launch Vehicles and Designations: OSC Antares 120
- Orbital Sciences Corp. Antares Faring (3.9 m / 3.450 m / ID)
- Performance Estimates: Vandenberg AFB ~ 2,000 kg (Per OSC Performance Charts)
- Note: Taurus II Launch Vehicle Users Guide Release 1.3 April 2010 (For all references).
- Definition of Max. Payload: Separated S/C Mass (PAF Mass on User Spacecraft Side) Section 3.3 General Performance
- Separation System and any mission-unique cabling or components. Section 3.5 Payload Deployment
- Launch Vehicle Injection Errors: Section 3.4 Injection Accuracy
- Launch Vehicle Tipoff and Roll Rate Capacities: Section 3.5 Payload Deployment, 3.6 Payload Separation Dynamics
- Launch Vehicle Mission Time Line (Lift off to S/C Separation): Table & Figure 3.2 Mission Sequence of Events
- Attitude Rates and Stabilization Interfaces: Section 3.4 Injection Accuracy
- Fairings: Section 5 Payload Faring (3.9 m / 3.450 m) (OD/ID)
- PAF Payload Attach Fittings: Users Guide Section 5.0 Payload Attach Fittings
- Launch Vehicle PAF Center of Gravity (CG Maximums): Payload Users Guide Section 5.1.2.1 Mass Properties
- Environments: Users Guide Section 4.0 Payload Environments (General Payload Information)
- Load Limits: Users Guide Section 4.0 Payload Environments (General Payload Environments)
- Mission Unique Equipment/Services: Users Guide Section 8 (Optional Launch Vehicle Capabilities)
- Note: Antares: By launch Date Fy20 the dispersion on the launch vehicle should be acceptable for the mission.

Launch Configuration (Antares)
(3.9m/3.45m OD/ID)



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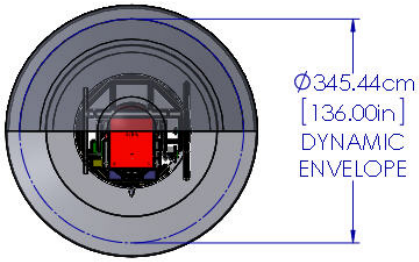
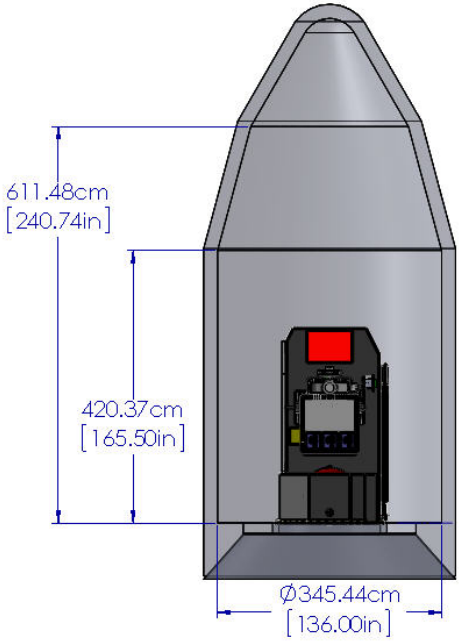
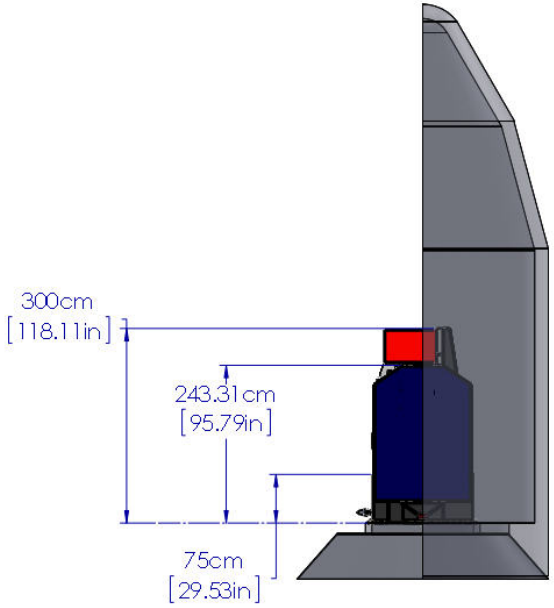
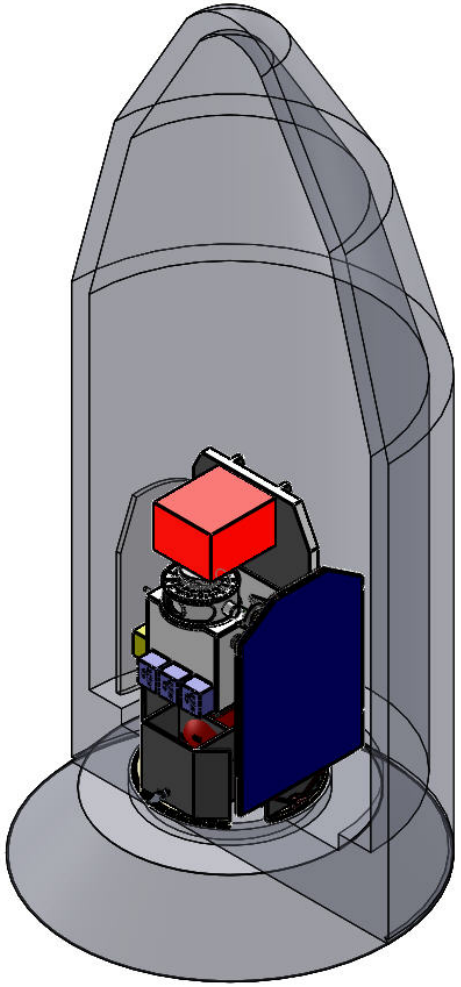
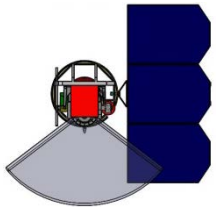








Falcon 9 (Block I / II) (5.2m/4.6m – OD/ID) Launch Vehicle



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- **Note: Falcon 9 (Block I / II) will meet the PACE Mission Requirements with Faring Volume / Payload Mass Margin +++**

- Launch Site: Cape Canaveral Air Force Station (CAFB), Florida
- Mass estimate : PACE ~ 1,000 kg (Plus 30% = ~1,300 kg)
- Space X Falcon 9 (Block 1 / 2) Faring (5.2 m / 4.6 m) (OD/ID)
- Performance: Sun Synchronous Orbit 700 km = ~ 6,320 / 7,345 kg (Per NASA LSP)
- The typical range of performance degradation is ~ 30-60 kg for the separation system TBD. Space X does not specify a separation system in its user guide.
- Note: Space X Falcon 9 (Block 1 / Block 2) (Users Guide Rev 1 / For all references).
- Definition of Maximum Payload: Separated S/C Mass (PAF Mass on User Spacecraft Side) Section 4.1 Performance
- Separation System and any mission-unique cabling or components. Section 5.4.1 Non Standard Services
- Launch Vehicle Injection Errors: 4.4 Mission Separation Accuracy
- Launch Vehicle Tipoff and Roll Rate Capacities: Section 2.3.3.2 Separation Accuracies, Mission Accuracies
- Launch Vehicle Mission Time Line GTO (Lift off to S/C Separation): Table & Figure 2.4.1.1 Sequence of Events
- Attitude Rates and Stabilization Interfaces: Section 2.3.3.2 Separation Accuracy
- Fairings: Section 5.1.2 Payload Faring (5.2 m / 4.6 m) (OD/ID)
- PAF Payload Attach Fittings: Section 5.3.1 Payload Attach Fittings (PAF)
- Launch Vehicle PAF Center of Gravity (CG Maximums): Payload Users Guide Section 5 General Payload Infor
- Environments: Payload Users Guide Section 5.2.3 Launch And Flight Environments (Payload Environment)
- Load Limits: Payload Users Guide Section 4.0 General Performance Capabilities

Lockheed Martin LMLV Athena II (92”/ 78.1” OD/ID)

Mission Design Laboratory

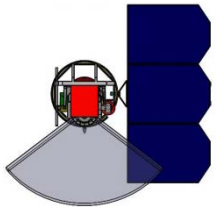
- **Lockheed Martin LMLV Athena I/II will not meet the PACE 2012 Mission Requirements for Faring Volume and LV Performance .**

- **Requirements: Launch Date Oct. 2017, Inclination 97º Altitude 700 km, Launch Site: VAFB Vandenberg Air Force Base Launch Vehicles and Designations: Lockheed Martin Athena I/II**
- **PACE Mass Estimate ~ 1,000 kg (Plus 30% = ~1,300 kg)**
- **Performance Estimates: Inclination 97º Altitude 700 km (1,110 kg per Lockheed Martin Corp.)**
- **Note: Lockheed Martin Launch Vehicle LMLV I/II Athena Users Guide (2010) Not Available**
- **Lockheed Martin Launch Vehicle LMLV I Athena I Users Guide (2000) Used for Data Hard-Copy**
- **Definition of maximum Payload: LMLV I Users Guide Section 2.2.1 Performance Factors: Excludes Payload Adapter, Separation System and any mission-unique cabling or components.**
- **Launch Vehicle Injection Errors: LMLV I Users Guide Section 2.3 Orbit Injection Accuracy**
- **Launch Vehicle Tipoff and Roll Rate Capacities: LMLV I Users Guide Section 2.4.1 Attitude Rates and Stabilization**
- **Launch Vehicle Mission Time Line (Lift off to S/C Separation): LMLV I Users Guide Section 2.1.3-1 & 2 Launch Trajectories and Sequence of Events**
- **Attitude Rates and Stabilization Interfaces: LMLV I/II Users Guide Section 2.41 Attitude Rates and Stabilization**
- **Fairings: LMLV I/II Launch Vehicle Payload Users Guide: Section 4.0 Spacecraft to Launch Vehicle Interfaces**

Lockheed Martin LMLV Athena I/II meets the DESDYNL Mission Requirements Faring Volume and LV Performance

- **PAF Payload Attach Fittings (Specifications): LMLV I Users Guide Section 4.1.2.1-1 Standard Payload Adapters Model 38, Model 47, Model 66.**
- **Launch Vehicle PAF Center of Gravity (CG Maximums): LMLV I Users Guide Section 3.2.1 Loads and Load factors**
- **Environments: LMLV I Users Guide Section 3.2 Launch And Flight Environments**
- **Load Limits: LMLV I Users Guide Section 4.1.2.1 Payload Adapters**
- **Mission Unique Equipment/Services: LMLV I Users Guide Section 9.0 System Enhancements**

Launch Configuration (Athena II)



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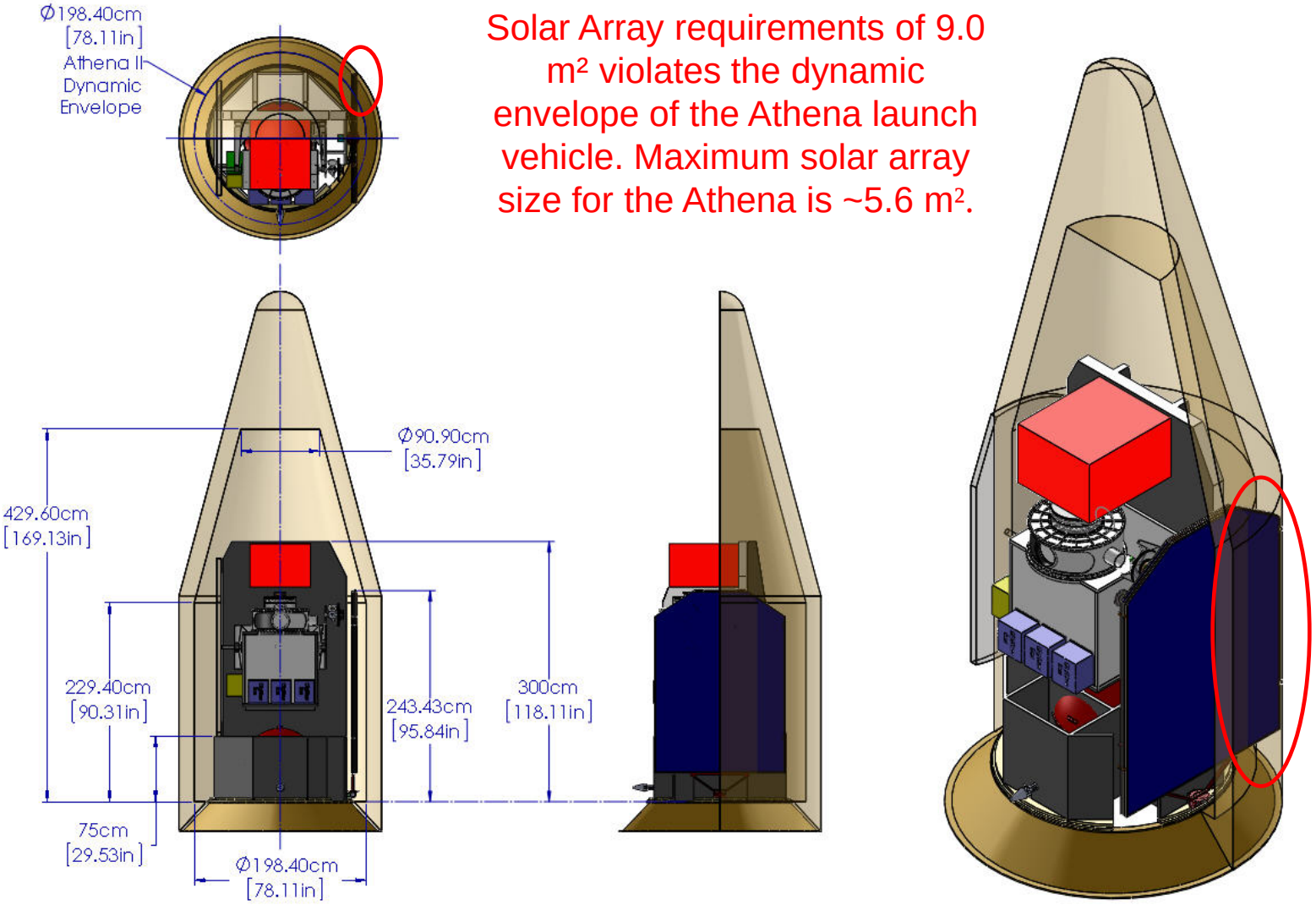
Solar Array requirements of 9.0 m² violates the dynamic envelope of the Athena launch vehicle. Maximum solar array size for the Athena is ~5.6 m².

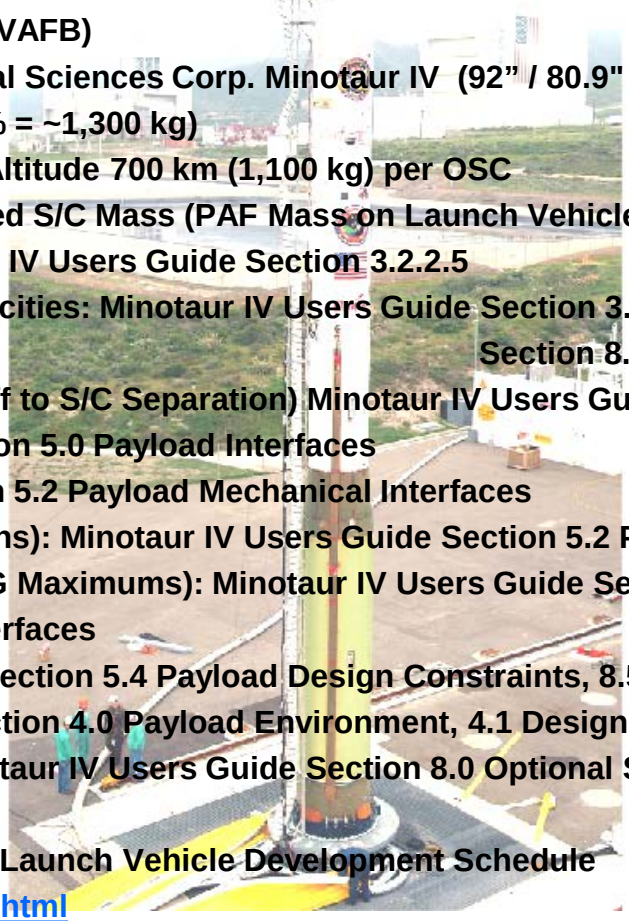


Orbital Sciences Corp. Minotaur IV (92”/ 78.1” OD/ID)

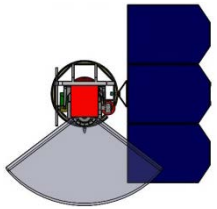
Mission Design Laboratory

- **OSC Minotaur IV will not meet the PACE 2012 Mission Requirements Faring Volume and LV Performance .**

- **Requirements: Launch Date Aug. 2017, Inclination 97º, Altitude 700 km,**
- **Launch Site: Vandenberg Air force Base (VAFB)**
- **Launch Vehicles and Designations: Orbital Sciences Corp. Minotaur IV (92” / 80.9" Fairing)**
- **PACE Mass Estimate ~ 1,000 kg (Plus 30% = ~1,300 kg)**
- **Performance Estimates: Inclination 97º, Altitude 700 km (1,100 kg) per OSC**
- **Definition of maximum Payload: Separated S/C Mass (PAF Mass on Launch Vehicle Side)**
- **Launch Vehicle Injection Errors: Minotaur IV Users Guide Section 3.2.2.5**
- **Launch Vehicle Tipoff and Roll Rate Capacities: Minotaur IV Users Guide Section 3.2.2.5 Orbit Injection Accuracies Section 8.2.1 Optional Separation Systems**
- **Launch Vehicle Mission Time Line (Lift Off to S/C Separation) Minotaur IV Users Guide Section 3.3 Figure 3-1**
- **Interfaces: Minotaur IV Users Guide Section 5.0 Payload Interfaces**
- **Fairings: Minotaur IV Users Guide Section 5.2 Payload Mechanical Interfaces**
- **PAF Payload Attach Fittings (Specifications): Minotaur IV Users Guide Section 5.2 Payload Mechanical Interfaces**
- **Launch Vehicle PAF Center of Gravity (CG Maximums): Minotaur IV Users Guide Section 5.4 Payload Design Constraints, Section 8.5.3 Mechanical Interfaces**
- **Environments: Minotaur IV Users Guide Section 5.4 Payload Design Constraints, 8.5.5 Payload Environments**
- **Load Limits: Minotaur IV Users Guide Section 4.0 Payload Environment, 4.1 Design Load Limit Factors**
- **Mission Unique Equipment/Services Minotaur IV Users Guide Section 8.0 Optional Services**
- **Administrative Process for Minotaur IV**
- **Orbital Sciences Corporation Minotaur IV Launch Vehicle Development Schedule**
- **http://www.orbital.com/video/SBSS/video.html**



PACE 2012 Launch Vehicle Summary



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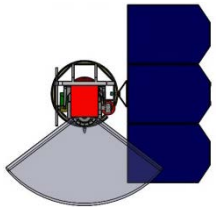
- **PACE Mass Estimate ~ 1,000 kg (Plus 30% = ~1,300 kg)**

- **For the PACE mission the OSC Antares 120 (3.9m/3.45m OD/ID) and the Falcon 9 (Block I / II) (5.2m/4.6m – OD/ID) launch vehicles meet the PACE mission Faring Volume and Launch Vehicle performance requirements with sufficient margin for S/C growth.**
- **The OSC Antares 120 (Formally Taurus II) will meet the PACE mission requirements with additional margin for Faring Volume and Launch Vehicle Performance. Additionally this vehicle can launch from: Vandenberg AFB or the Kodiak Island, Alaska (KLC / Kodiak - Launch Complex) which may be a NASA Mission / Commercial advantage.**

- **The Space X Falcon 9 (Block I / II) will meet the PACE mission requirements with Launch Vehicle Performance +++++ and Faring Volume +++++.**
- **LMLV Athena IIC (Faring 92”): Faring size and Performance below PACE mission Requirements.**
- **Orbital Sciences Corp. Minotaur IV (Faring 92”): Faring size and Performance below PACE mission Requirements.**

Internet Information



- **Launch Vehicle Information**

Orbital Sciences Corporation: http://www.orbital.com/SpaceLaunch/Taurus/index.html

Space X: http://www.spacex.com/falcon9.php

Lockheed Martin: http://www.lockheedmartin.com/news/press_releases/2010/0325_ss_athena.html

Athena Rocket Family http://en.wikipedia.org/wiki/Athena_%28rocket_family%29

Point of Contact:

For Technical Details, Please Contact Us At:
Phone: 480.814.6566
E-mail: minotaur@orbital.com
Web Site: http//www.orbital.com

Program Office:

Additional information should be obtained from the USAF OSP Office
USAF SMC Det 12/RP
3548 Aberdeen Avenue S.E.
Kirtland AFB, NM 87117-5778
(505) 846.8957 FAX: (505) 846.5152

- **Planetary Systems Corp. (Light-Band Separation System)**

http://www.planetarysystemscorp.com/Technology Transfer Information

Vandenberg Air Force Base (VAFB) http://www.vandenberg.af.mil/

Kodiak Island Launch Site: http://www.akaerospace.com/klc_overview.html