## Low-Density Supersonic Decelerators An Update

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# Mars Entry, Descent, and Landing Technology State of the Art



#### Square-Cube Law





$$F_{drag} = rac{1}{2}
ho v^2 C_D A$$
  
 $F = ma$   
 $a_{drag} = rac{1}{2}
ho v^2 rac{C_D A}{m}$ 

 $\begin{aligned} A \sim L^2 \\ m \sim L^3 \\ a_{drag} \sim \frac{A}{m} \sim \frac{1}{L} \end{aligned}$ 

#### LDSD: Low-Density Supersonic Decelerator



#### 6m Attached Torus Overview





#### 8m Attached Isotensoid



#### 30.5m Supersonic Parachute







#### Transonic Dynamics Tunnel, October 27, 2014



#### Transonic Dynamics Tunnel, October 30, 2014



#### Rocket Sled PDV2 SSRS, February 18, 2015

## Peak Load ~120k lbf



#### Rocket Sled SDVE2 SIAD-E, April 17, 2015



#### SFDT2 Balloon Launch, June 8, 2015



#### SFDT2 High Altitude Supersonic Flight



#### SFDT2 High Resolution Deployments



### SFDT2 Recovery



#### SFDT2 Damage Progression

LDSD S501-2 2015-06-08 IRIC Time 21:37:33.637860 Time from Drop 153:192 s Mach No. 2.25 Dynamic Pressure 539 Pa Total AoA 3.1 deg SSRS Axial Load 75060 lbf LDSD SPDT-2 2015-06-08 LRtc Time 21:37:33.641563 Time from Drop 153.196 s Mach No. 2.25 Dynamic Pressure 538 Pa Total AoA 3.1 deg SSRS Axial Load 77532 lbf



LDSD SF01-2 2015-06-08 IRIC Time 21137:33.645267 Time from Drop 153.199 s Mach No. 2.24 Dynamic Pressure 537 Pa Total AoA 3.1 deg SSRS Axial Load 79292 lbf

LDSD SEDT-2 2015-06-08 IRIG Time 21:37:33.648971 Time from Drop 153.203 s Mach No. 2.24 Dynamic Pressure 535 Pa Total AoA 3.0 deg SSRS Axial Load 78222 lbf



#### SFDT-2 Investigation Status

- SFDT-1 yielded best set of data on a supersonic parachute, ever
- SFDT -2 was even better
- Parachute advanced through inflation process much further than in SFDT-1 and ultimately failed at full inflation
  - SFDT-1 remedy was successfully demonstrated
- Three families of hypotheses being actively worked for SFDT-2 parachute
  - Material and fluid inertial forces significantly larger than expected
  - Pressure forces significantly larger than expected and asymmetric
  - Material/Seam and Joint strength not as expected under loading environment
- We are in the midst of a paradigm shift in our understanding of supersonic parachutes

#### Key LDSD Accomplishments in the Past Year

#### <u>Technologies</u>

- Successfully conducted 2<sup>nd</sup> Supersonic Flight Dynamics Test
- Successfully matured two separate supersonic decelerators to TRL-6
  - SIAD-R and ballute both largest ever of their kind and both exceeded performance expectations
- Successfully conducted structural and inflation test of 8m SIAD-E
  - SIAD-E progressing towards TRL-5
- Successfully conducted three separate structural tests of a 30.5 m parachute
  - Each test yielded valuable insight into design and construction details of large parachutes
- Continued to rewrite the textbook on supersonic parachutes
  - Lessons learned have been shared with industry and numerous flight projects utilizing soft good decelerators

#### **Documentation**

- Presented over two dozen papers at aerospace technical conferences
  - Including five full sessions at the AIAA Aerodynamic Decelerator Systems Conference
- Completed 400+ page SFDT-1 Post-Test Report
- Completed draft of SIAD-R Technology Archive Report
  - Continuing to progress on other Technology Archive Report