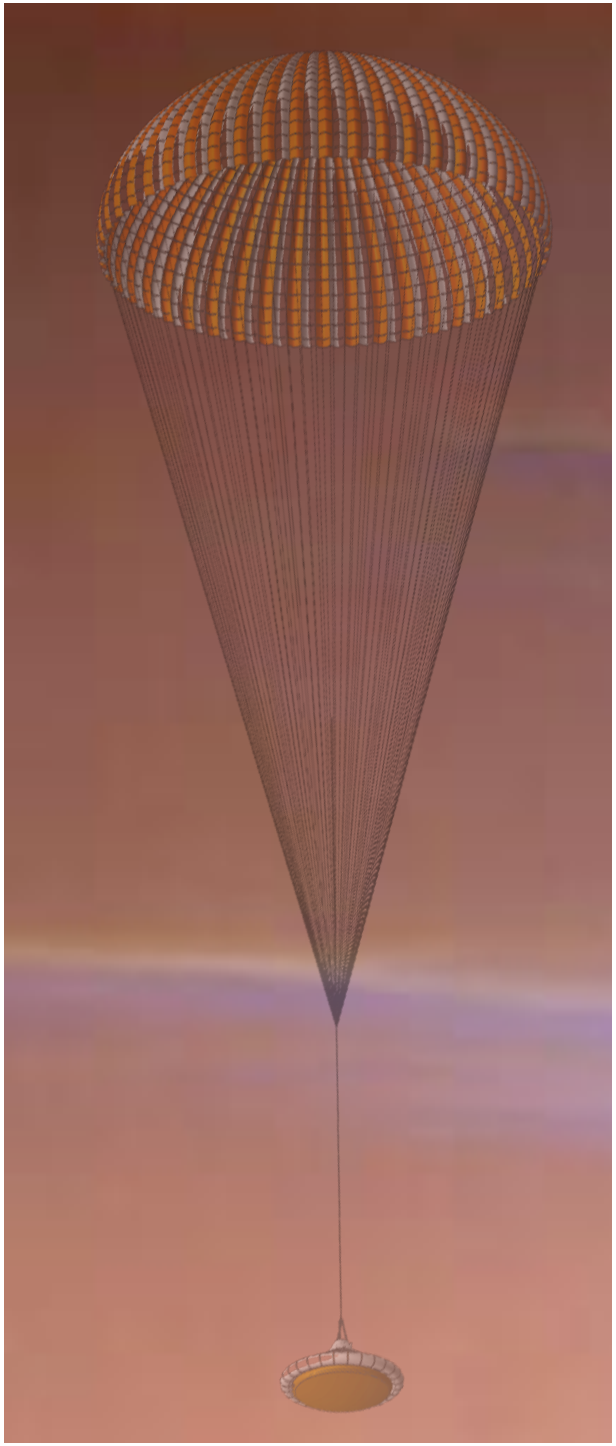


SIAD / LDSD Technology Formulation Experiences

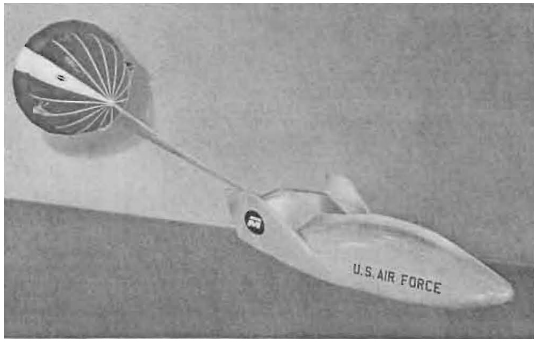
Mark Adler

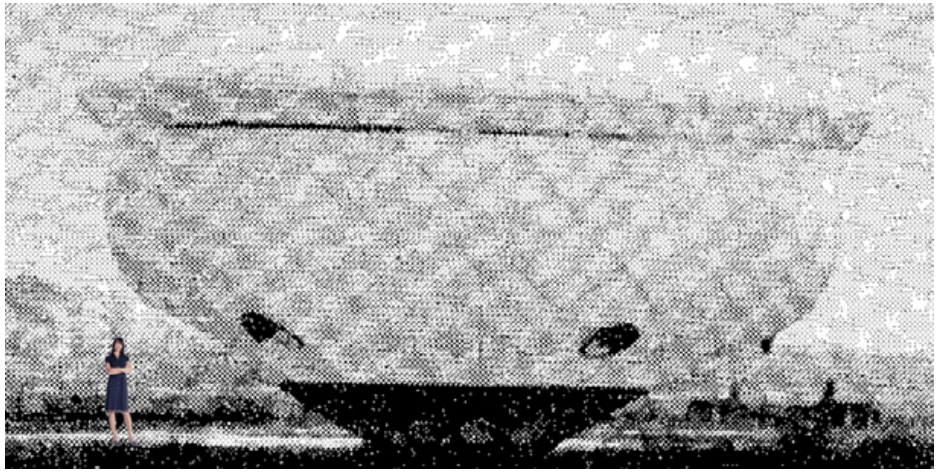
June 4, 2011

8th International Planetary Probe Workshop Short Course

Supersonic Inflatable Aerodynamic Decelerator

- *Problem*
  - Mars entry masses getting higher, launch vehicle fairings aren't
  - Ballistic coefficients go up, blunt body L/D limited to ~ 0.15 – 0.25
  - Eventually, can't slow down to Mach 2 and so can't deploy parachute before hitting the ground
- *Solution*
  - Deploy a different drag device at Mach 3 to 5, higher altitude
  - Can't be a parachute (lousy drag, deployment failures)
  - Use a continuous inflated structure to increase the presented area
  - Initial IAD developments through the 1960's



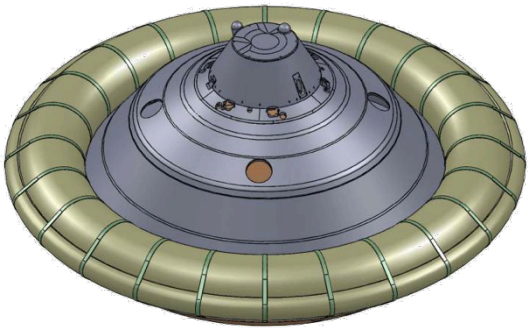


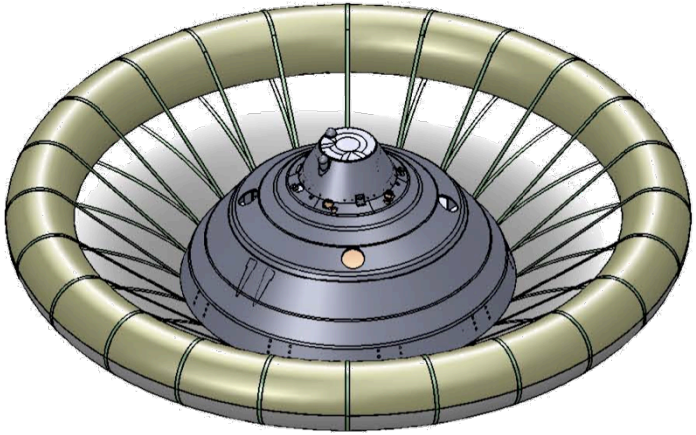
August 2010

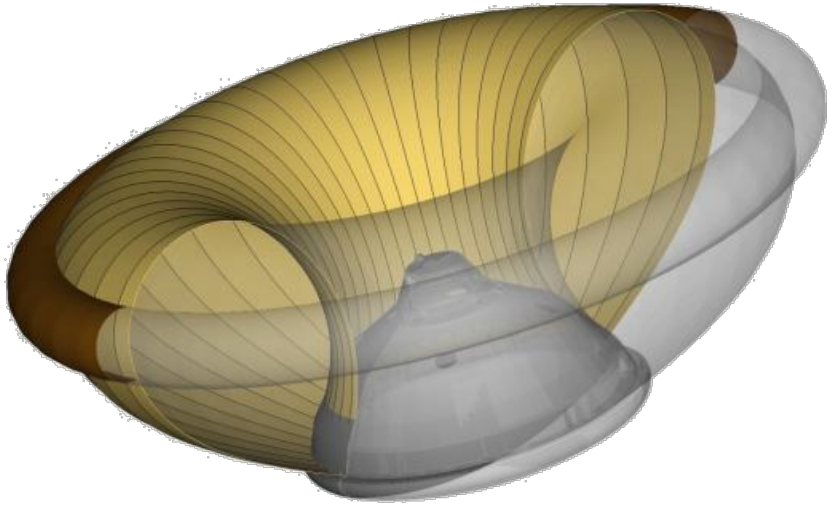
- Assigned the task of formulating a SIAD technology development
  - Bring the SIAD to TRL-6 in time for use in the 2018 Mars mission
  - To do this, fly SIADs at condition in Earth's stratosphere
  - Up to $150M from OCT, plus at least 25% co-funding from outside OCT
- Expectation
  - In addition to other benefits, a large-enough SIAD could in theory allow the use of a subsonic parachute instead of a supersonic parachute
  - The qualification of a new, large subsonic parachute would be much less expensive than a new, large supersonic parachute
  - The expectation was not apparent at the start, but became apparent when we came up with the "wrong" answer
- **LESSON: Dig deep to understand the motivations of the sponsor, in as great detail as possible — the motivations may be complex (both technical and programmatic), and some may intentionally not be stated openly**
  - **Apply alcohol liberally**

What SIAD?

- What type?
  - Isotensoid? Tension cone? Attached torus?
- What size?
  - 6 meters? 10 meters? 14 meters?
- What Mach?
  - Mach 5? Mach 4?
- What would the benefits be at Mars, and where should we draw the line?







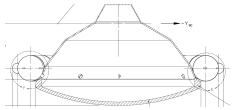
Previous Studies

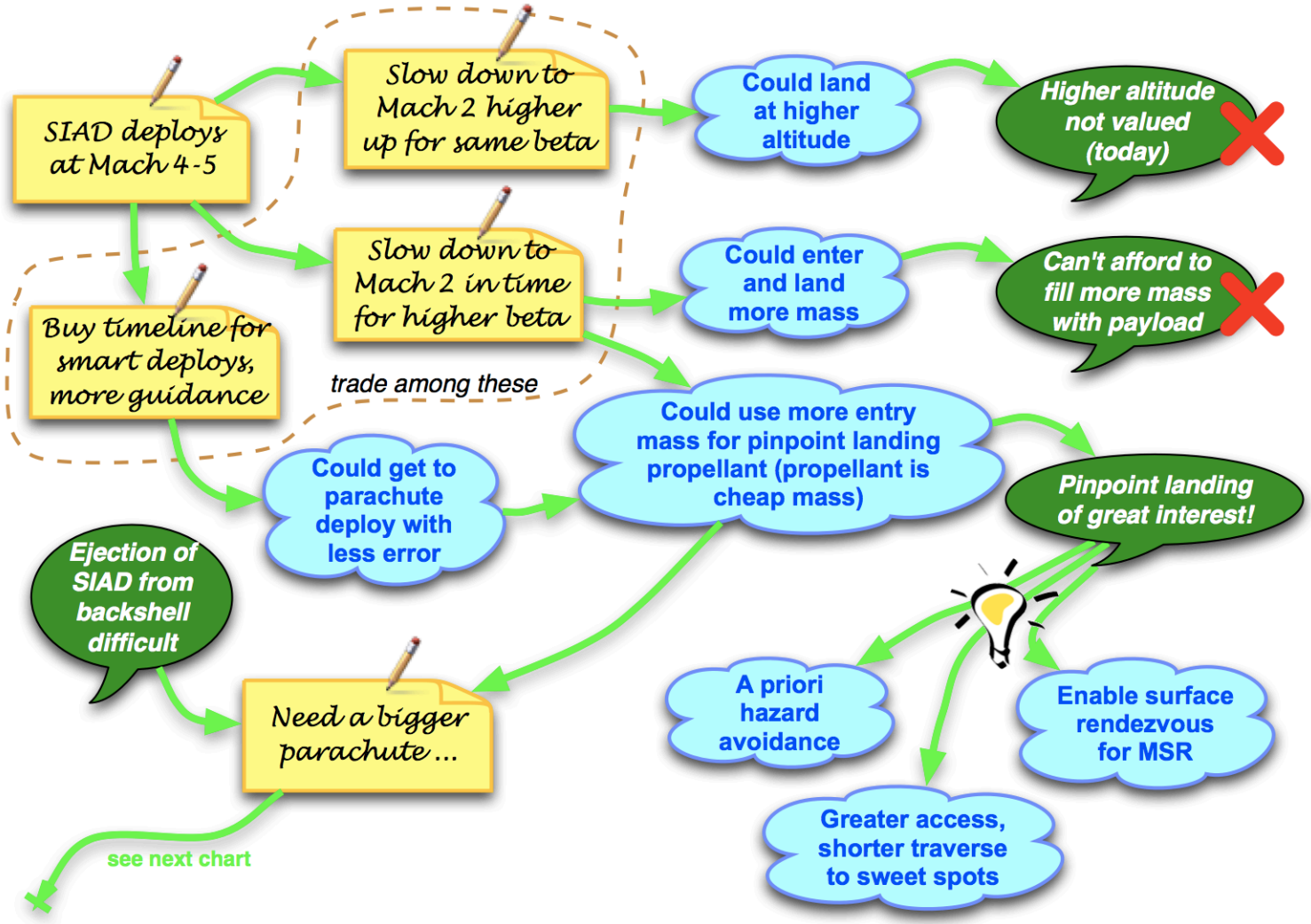
- The SIAD initiative had been inspired by various papers, studies, theses
- *None* of the previous work provided the necessary application studies to be able to answer the questions we had
- The SIAD project had to conduct its own application studies *in parallel* with planning the project and running contracts with potential SIAD vendors in order to meet the 2018 schedule
  - The parallel efforts resulted in inefficiency in studying multiple options by multiple contractors, as well as considering different sizes and velocities in the design of the test architectures
- **LESSON: If you can, arrange to have enough time to do detailed application trade studies before having to enter a design phase for the project — previous trade studies will probably not be sufficient, since they didn't have your exact problem in mind.**
  - **Allow six months**

Co-Funding

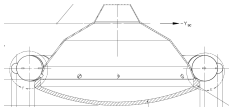
- The 25% co-funding requirement is difficult
  - The most immediate user of a SIAD, SMD, doesn't need it yet
    - They don't want it for 2018, the schedule driver for the SIAD project!
  - *No* funding source has a bunch of money laying around for unanticipated technology projects, for at least the next few fiscal years
- We had to figure out how to motivate SMD
  - Other sources might be able to contribute small amounts, if interested, but only SMD appears to have sufficient resources, as well as near-term interests in Mars entries
- So what *does* SMD want?
- Answer: A larger supersonic parachute
  - SMD began an aborted parachute development in 2005
- At the same time we are realizing that in order to cash in on the SIAD performance, taking into account other programmatic realities, you need a larger parachute anyway
- There are many technical and programmatic factors to consider

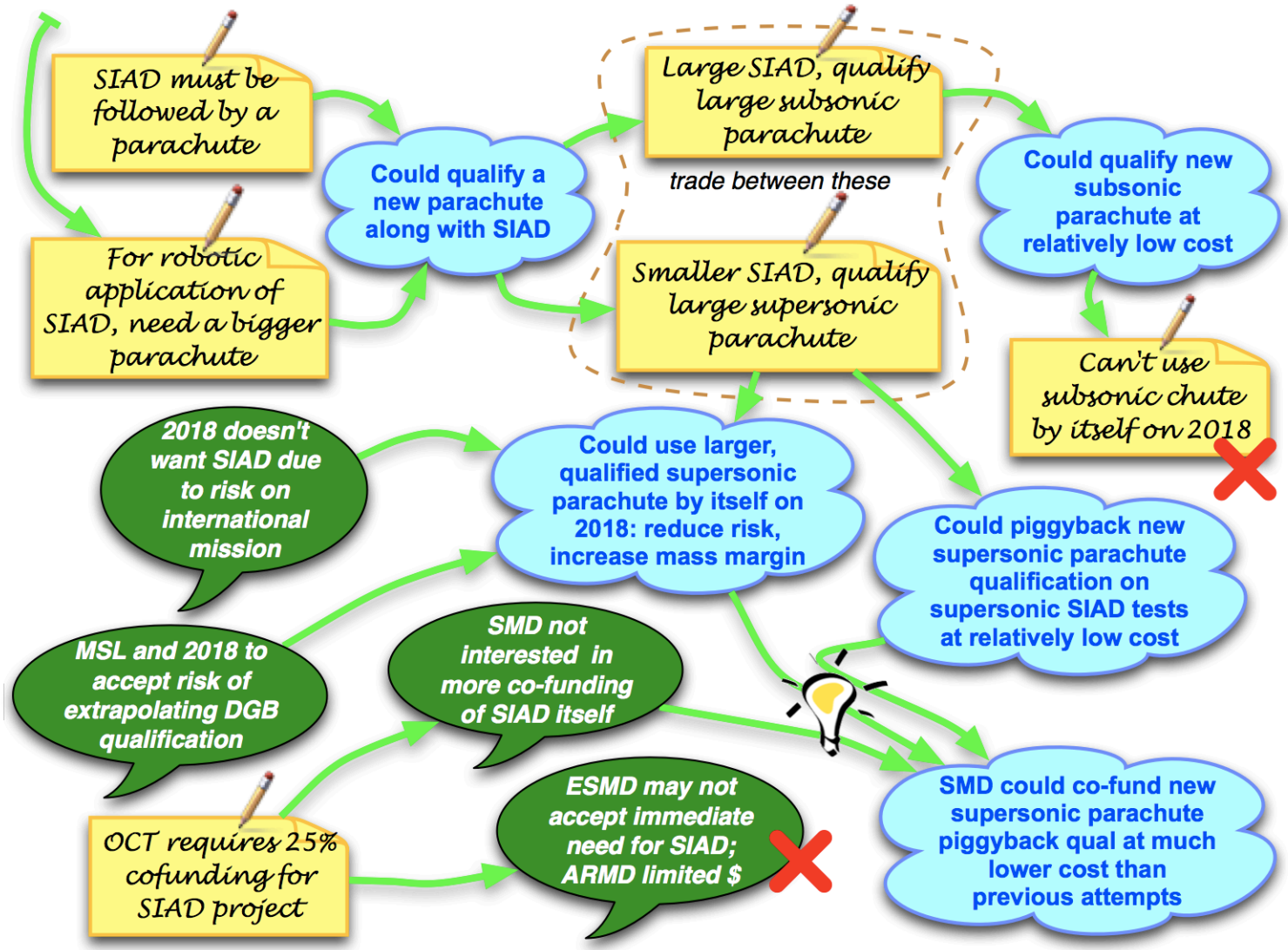
Robotic Mars Benefits of SIAD





SIAD, Parachute, and Co-funding

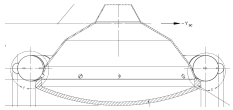




Multiple Sponsors

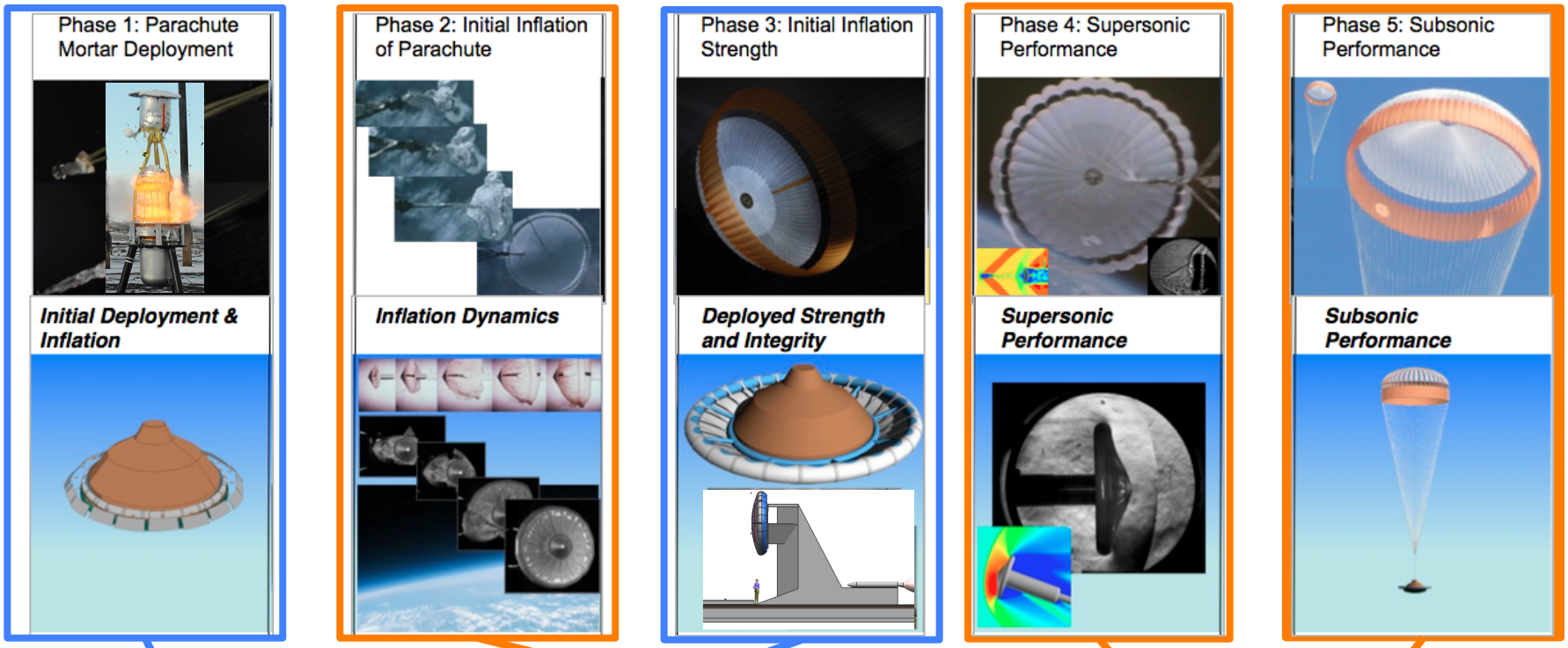
- So, we add a 30-meter supersonic ringsail parachute development to SIAD (as a result, the project name will change to LDSD)
- **LESSON: Multiple sponsors will likely require a much more complex strategy to maintain interest and funding when those funds are inevitably challenged**
- **Even without a 25% requirement, multiple sponsors, as well as non-sponsor cheerleaders, are essential to the survival of a large technology project**
- **So deal with it**
- **Why:**
  - **There will always be more good ideas for technologies than money**
  - **When choosing among the things to fund, those with broader applications both within NASA and outside will be the winners since they will be easier for your sponsors to defend to their sponsors**
  - **Even when your project is underway, you are *always* in competition with other potential technology developments**

What the heck is TRL-6 anyway?



- Functionally, TRL-6 is sufficient development of a technology so that it can be applied in a flight project at PDR without adding significant risk to that flight project, as well as being affordable to that project
  - That doesn't tell you what to do though
- What does that mean for the SIAD and parachute?
  - We need to test devices that are as flight-like as possible
  - We need to test them at full-scale, and at the proper q and Mach
  - We need to provide a cost-effective means for the project to *qualify* (bring to TRL-8) their actual devices as part of their V&V process
  - We need to provide enough information to know exactly what we built and how we built them, how we tested them, and what the results were, and how to model the performance of the devices in EDL simulations

Five Pillars of Soft-Goods Testing



Design Verification

Full scale hardware testing to verify design functionality & integrity

Flight Dynamics

Supersonic and subsonic flight testing to verify flight dynamics and aerodynamic performance

Credit: Tom Rivellini

Two Key Kinds of Tests

- Flight Dynamics
  - Supersonic, expensive (~$10M each), tests *not* repeated by flight project
  - Provide the information to build an aerodynamic database for the devices so that they can be used by a project without repeating this test
  - Show that the devices deploy and operate properly supersonically, well enough that the project does not have to repeat this test
  - Measure their performance as a *system*, where they can interact
- Design Verification
  - Subsonic (or low supersonic), inexpensive (~$1M or less each), used by project for device qualification
  - Test basic operation of the devices at dynamic pressure (not Mach)
  - Qualify the strength of the devices at greater than flight loads
- **LESSON: Carefully consider how the technology will be used by the infusing project, and what they will need to do to complete your work for the actual devices they develop and use**
  - **We created an "Infusion PI" role on our project for this purpose**

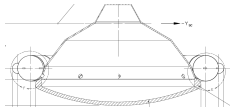
2018 Focus

- The 2018 schedule driver was a severe one
  - We were driven to a laser-focus on the specific SIAD and parachute devices for integration in the 2018 vehicle
- This wasn't good
  - The OCT sponsor (despite having decreed the 2018 requirement) felt that the result of the project would be too specific and not extensible enough for other applications
- Independently we were learning that due to various realities, such as the 20-month lead time for the solid rocket motors we needed, that the 2018 schedule was not realizable
  - We reached agreement with the OCT and SMD to extend the project to around the time of the 2018 PDR, which would not allow incorporation of the SIAD in the 2018 design, but would allow leaving space for larger parachute as a possible drop-in between PDR and CDR
- We then reconsidered the laser focus of the developments

Extensibility

- When bringing a technology to TRL-6, especially something like aerodynamic decelerators which inherently have issues with scaling to different sizes, extensibility is problematic
- Approach 1:
  - Develop and test exactly the devices needed for the first application, and claim that “We will learn a lot about these sorts of devices” in the process of so doing.
- Approach 2:
  - Perform exploratory investigations on the range of devices and sizes, effectively bringing devices like them to TRL-5. Leave it to the infusing project to complete the development of their specific devices to TRL-6.
- Neither approach would satisfy OCT, and #2 would not satisfy SMD
  - OCT wants TRL-6 (or even TRL-7), and at the same time doesn’t want something that is only useful to one directorate
- Need to use *both* approaches in a balanced way

Bringing Balance to the Force



- The project is now developing an approach to both bring specific devices to TRL-6, with some extensibility, *and* using the test capability that is developed to test larger, more flexible SIADs to provide a basis for other applications outside of SMD (e.g. crewed Mars mission precursors and cargo missions)
  - Explore the rigidity hypothesis for the attached torus to allow significant extensibility
  - Explore large SIADs both to learn the characteristics of more flexible devices and to enter the regime of higher ratios of entry body to parachute size
- **LESSON: Carefully consider not only the first application of your technology development, but *all* applications and how your developments can be scaled or modified to those applications without having to repeat the expensive flight tests (they may not be done again for a long time)**
  - **As an example, the Viking BLDT tests of 1972 have been relied on for all of our Mars missions for almost 40 years**

Summary

1. **Really understand the motivations of your sponsor(s)**
2. **Take the time to do your own application trade studies**
3. **Get multiple sponsors/supporters and then construct your technology development to scratch all of their itches in order to survive funding challenges**
4. **Figure out what TRL-6 (or TRL-7) means to you by carefully considering what the infusing flight project will need to do to use your technology — ideally get someone from that kind of flight project to help you**
5. **Consider how to construct your technology development to be applicable to a range of flight projects well into the future — if your development is expensive, chances are that it won't be done again for a long time**