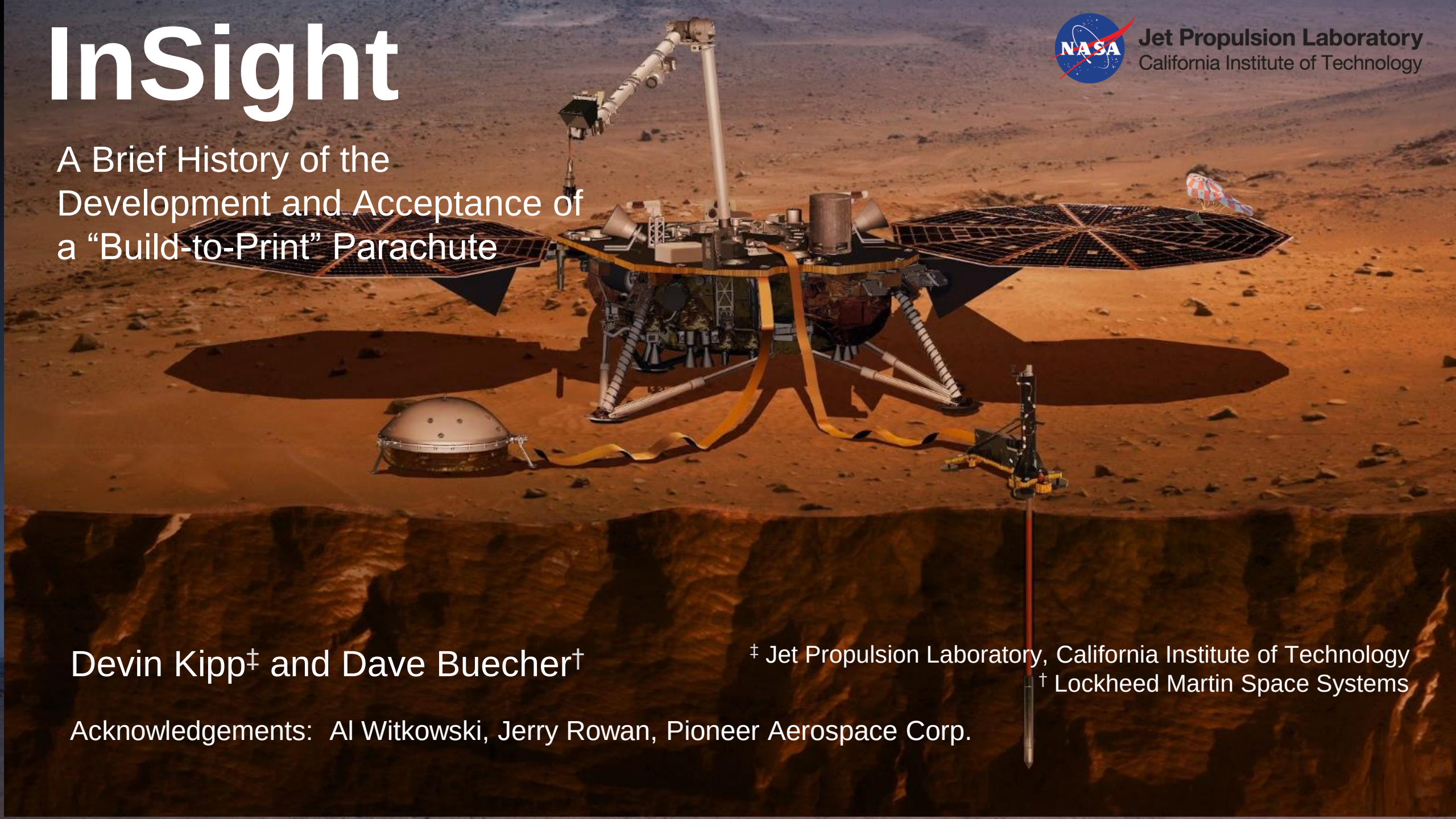
InSight

A Brief History of the Development and Acceptance of a “Build-to-Print” Parachute



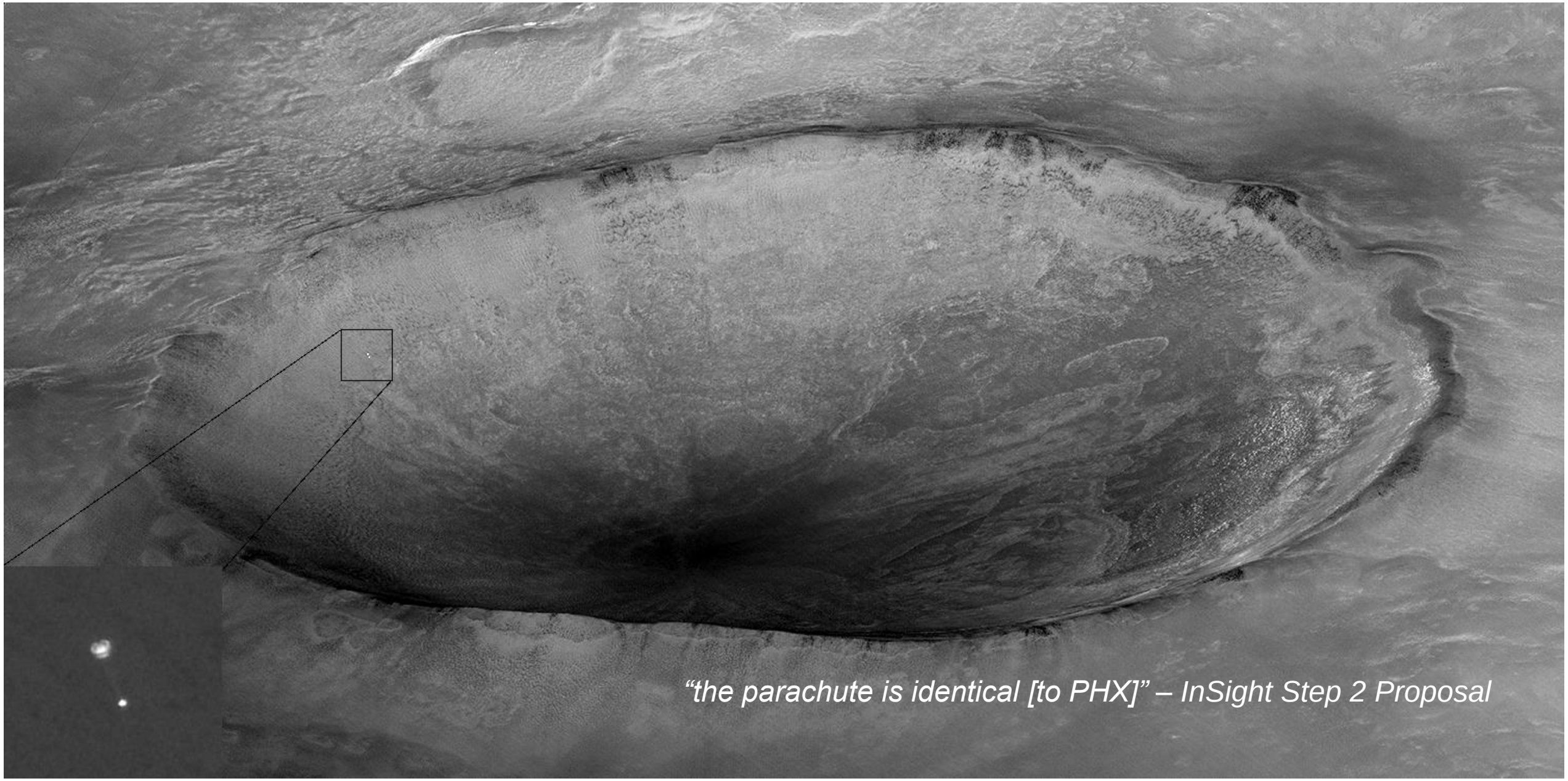
Jet Propulsion Laboratory
California Institute of Technology

Devin Kipp‡ and Dave Buecher†

‡ Jet Propulsion Laboratory, California Institute of Technology
† Lockheed Martin Space Systems

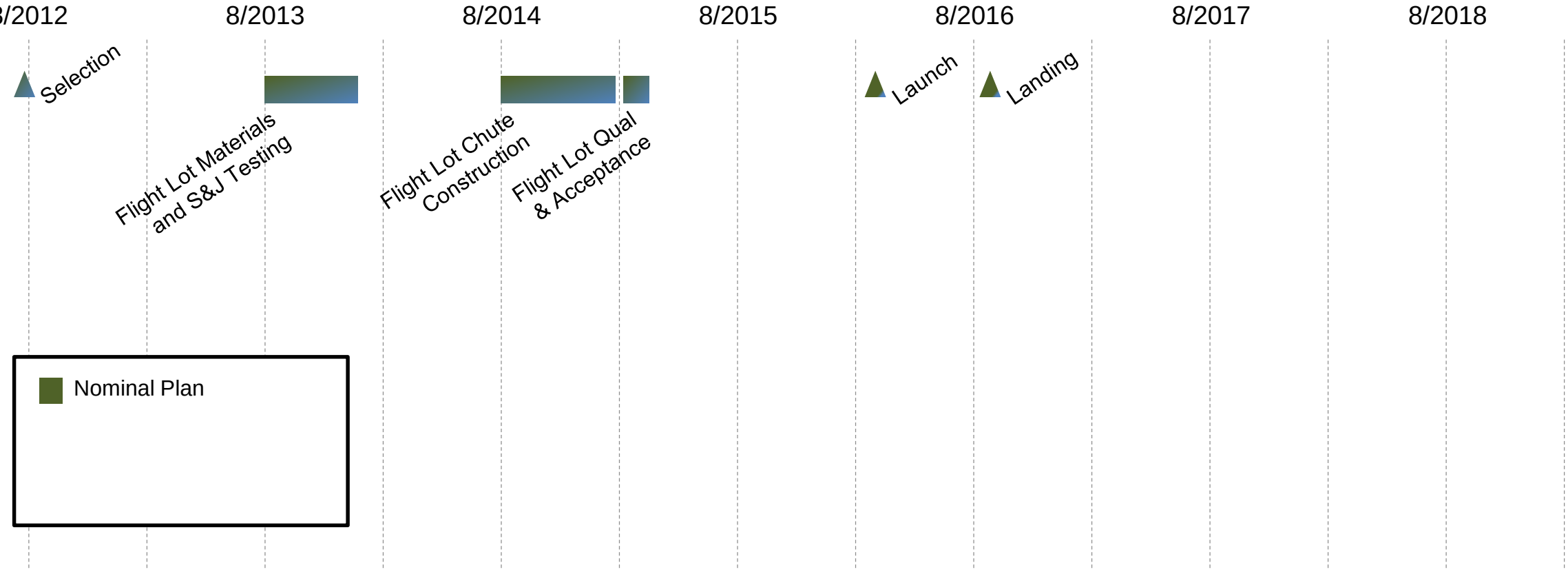
Acknowledgements: Al Witkowski, Jerry Rowan, Pioneer Aerospace Corp.

Mars Phoenix Heritage



“the parachute is identical [to PHX]” – InSight Step 2 Proposal

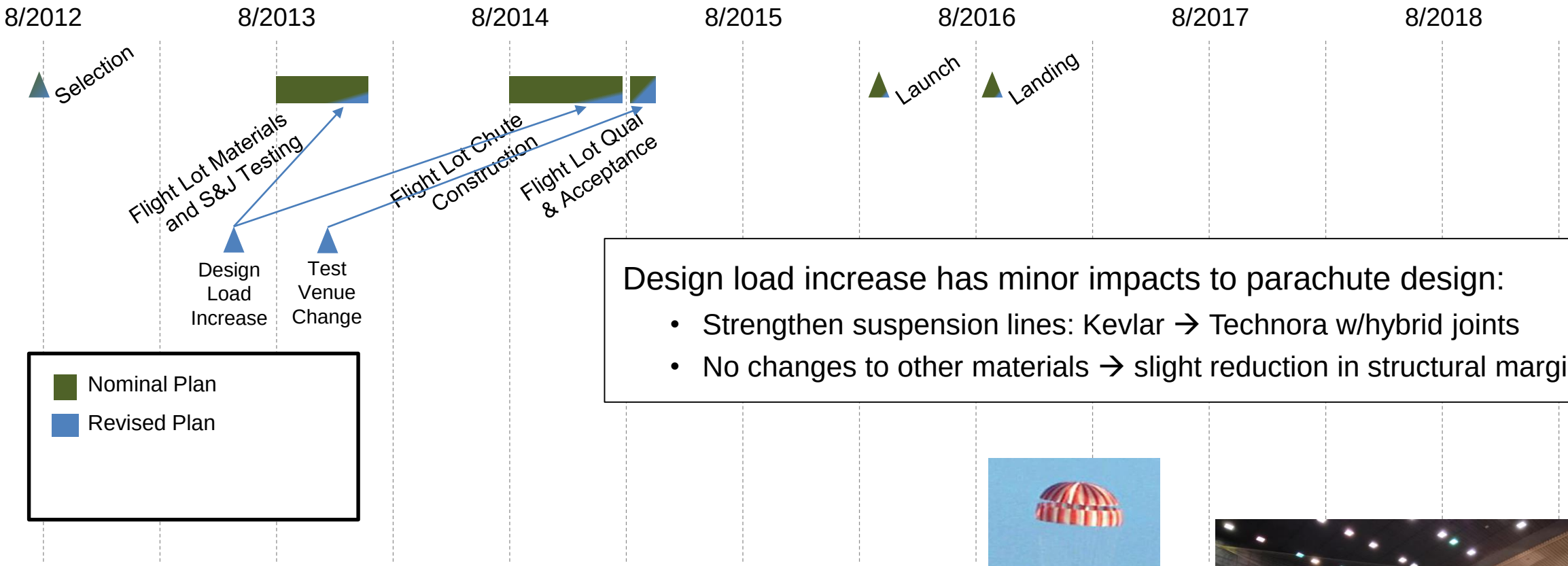
Parachute Plan



Initial plan:

- *"identical" = design, materials, construction, test program, etc…*
- Include healthy schedule margin to accommodate any setbacks during development and test

Parachute Plan, Revision 2 (Requirements Creep)

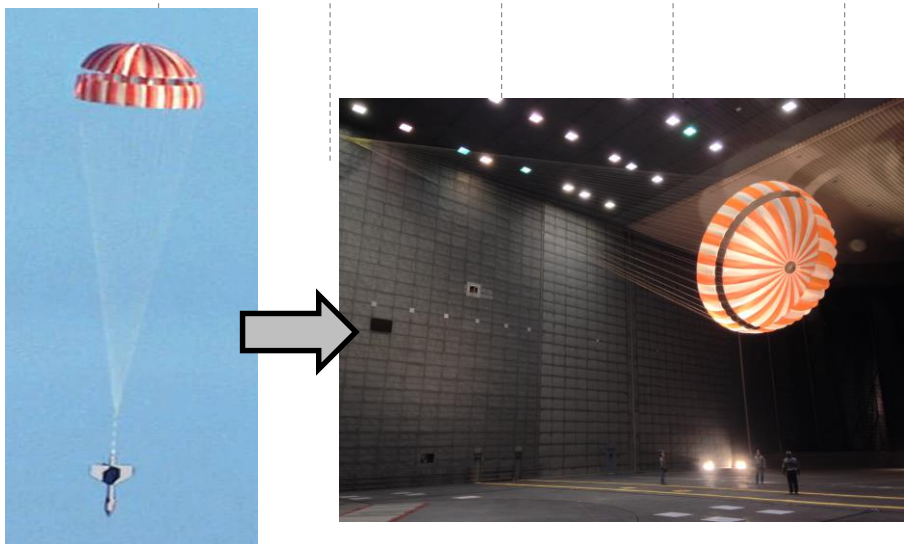


Design load increase has minor impacts to parachute design:

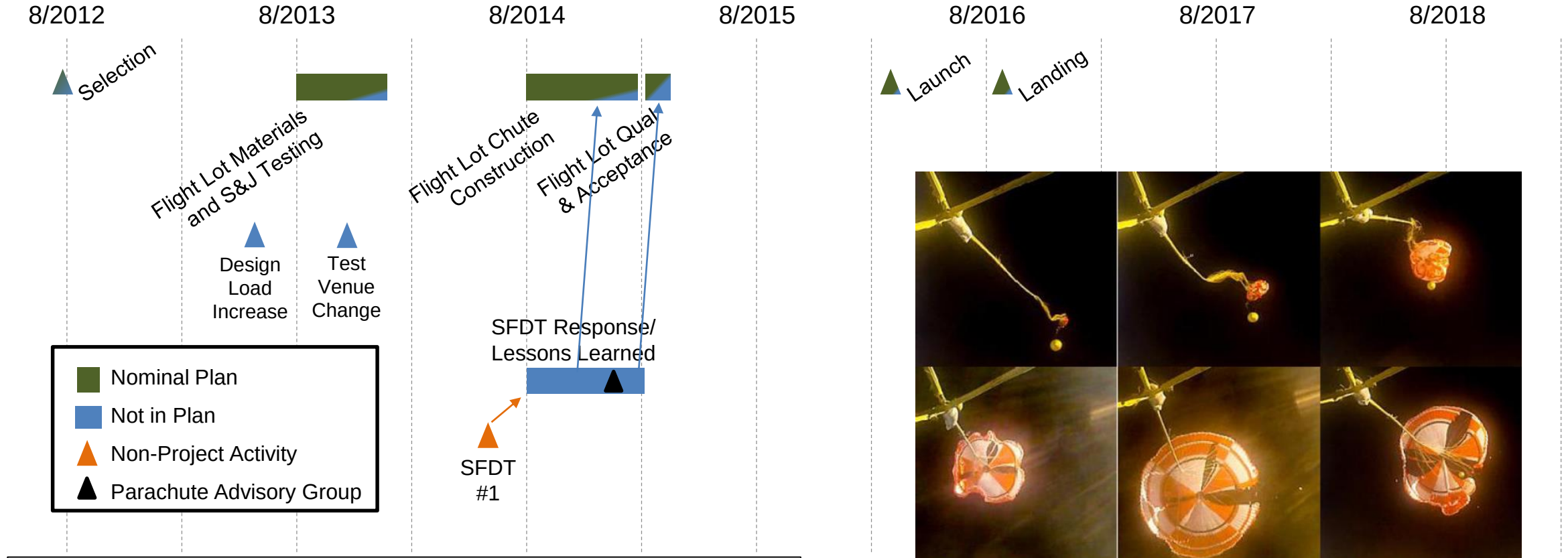
- Strengthen suspension lines: Kevlar → Technora w/hybrid joints
- No changes to other materials → slight reduction in structural margins

Test venue change enables test campaign improvements:

- Better control/repeatability of test conditions
- Better instrumentation and video of deployment/inflation



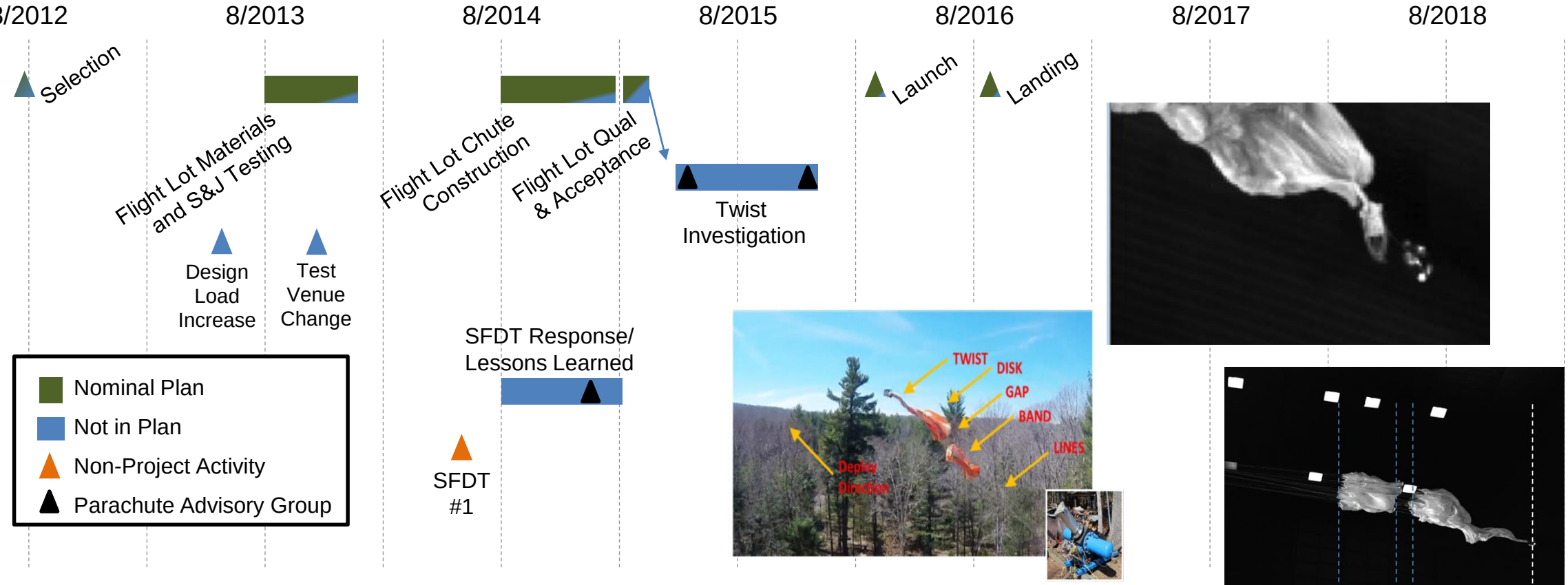
Parachute Plan, Revision 3 (SFDT #1 Response)

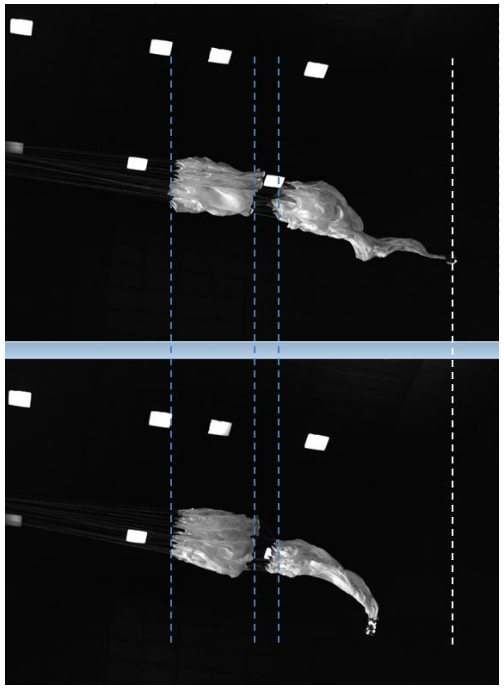


Incorporated multiple lessons learned:

- Sensitivity to dimensional variation
  - Augmented inspection, some re-work
  - Augmented LS-DYNA analysis
- Supersonic inflation stress > subsonic inflation stress
  - Augmented NFAC testing to include higher loads

Parachute Plan, Revision 4 (Parachute Twist)

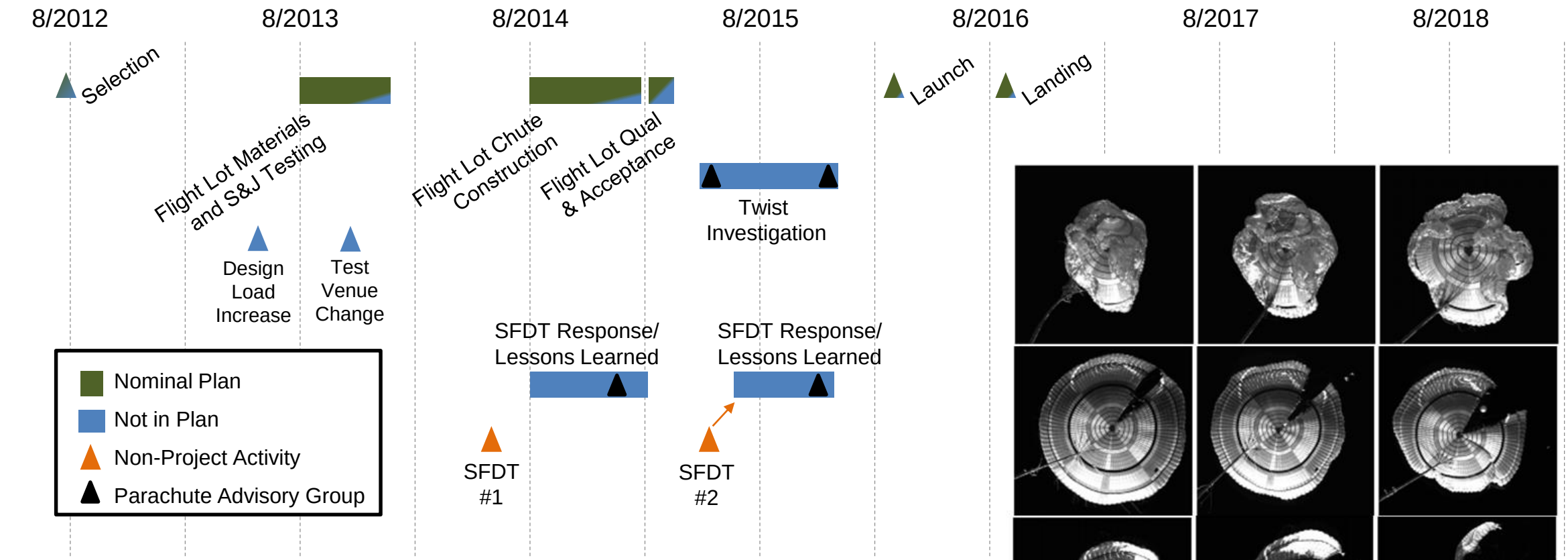




Discovered previously unobserved twisting phenomenon in NFAC:

- Confirmed that twisting is linked to parachute packing method
- Developed alternate packing method which eliminated twist
- Performed ‘fly-off’ of parachutes packed using both methods

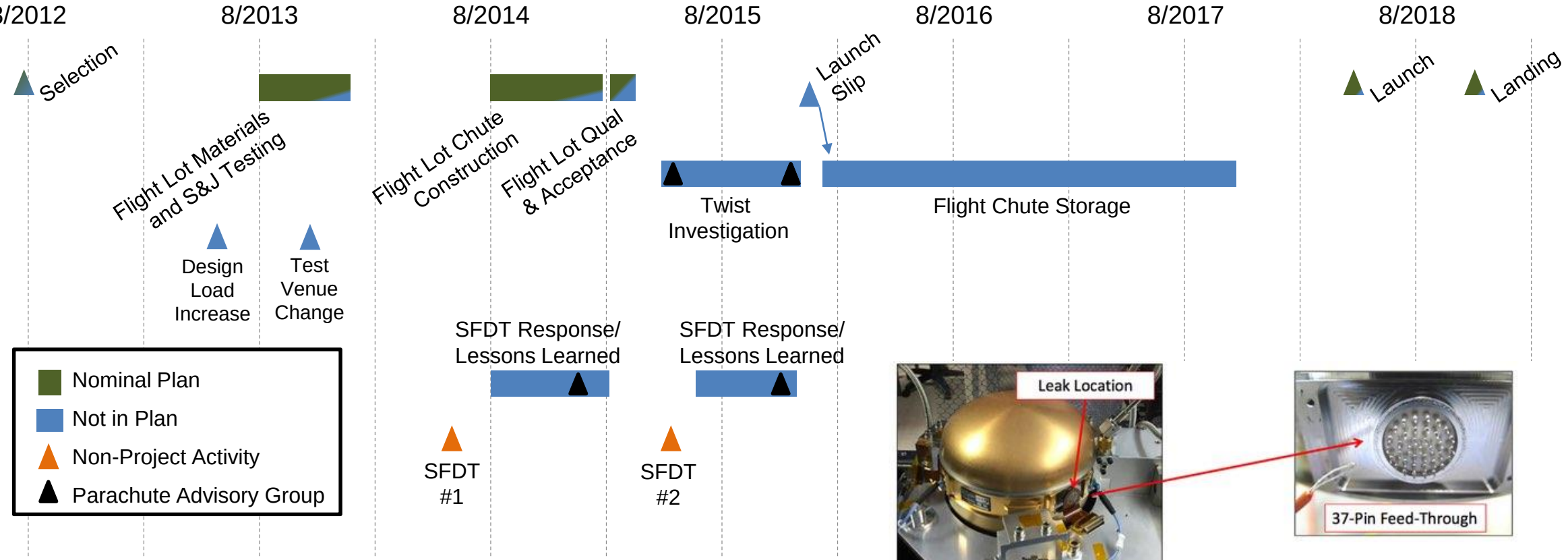
Parachute Plan, Revision 5 (SFDT #2 Response)

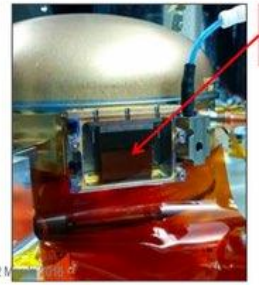


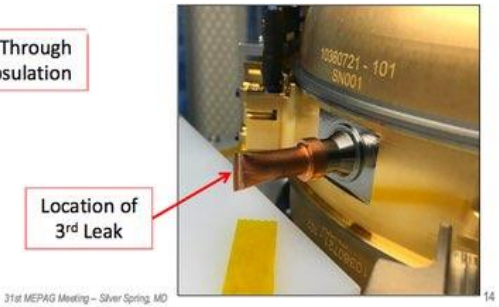
Closely followed post-flight investigation:

- InSight parachute already built and qualified, so limited ability to react
- All findings and recommendations could be reasonably addressed by InSight with no additional activities

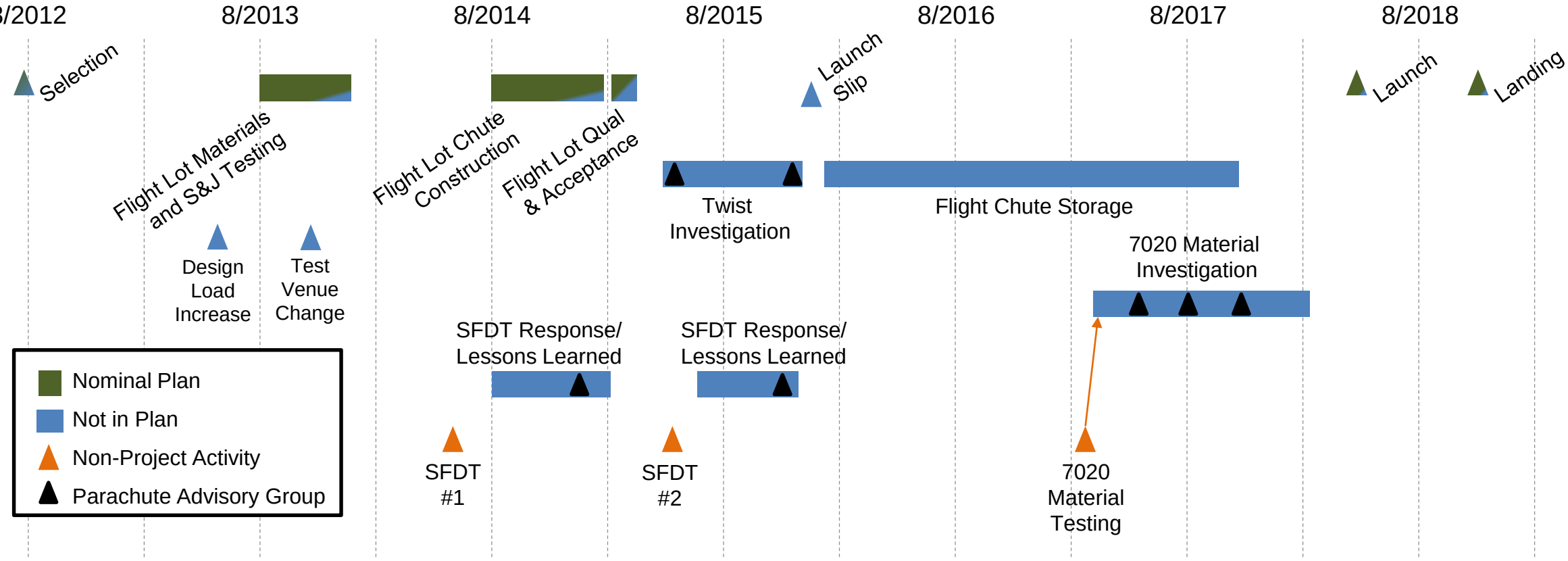
Parachute Plan, Revision 6 (Launch Slip)







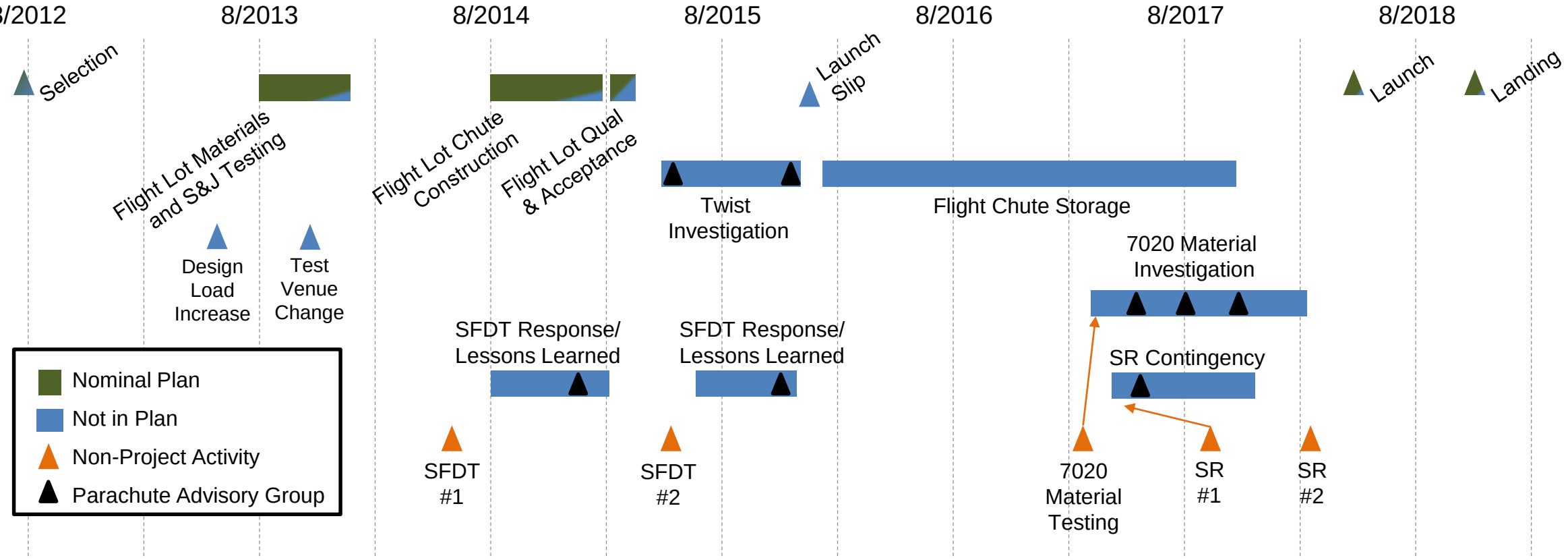
Parachute Plan, Revision 7 (Broadcloth Heritage)



Discovered that InSight broadcloth nylon is not the same as heritage material:

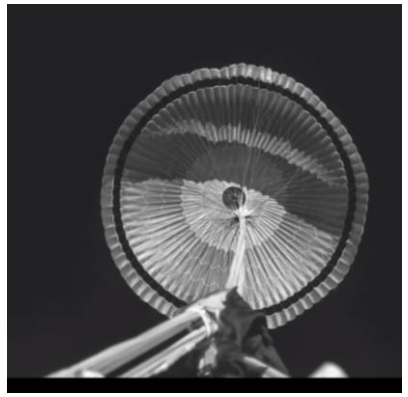
- Identified different material response after exposure to high temperature / high duration DHMR
- Different vendor, different additives, different response to DHMR environment (PIA-7020 is a spec, not a recipe)
- Performed enhanced material testing to range of flight-like environments where we had leveraged heritage
- Demonstrated InSight environments do not result in reduced performance

Parachute Plan, Revision 8 (ASPIRE SR1 and SR2)



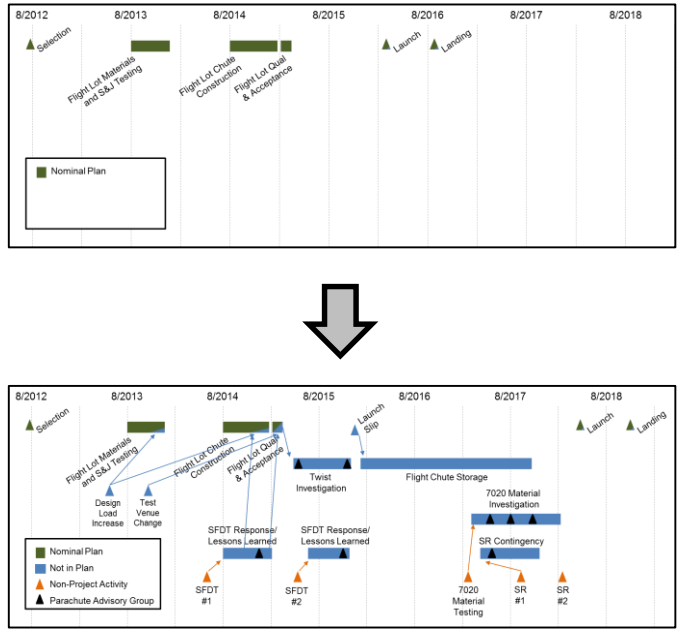
Watched ASPIRE flights anxiously:

- Opportunity for new learning (e.g. risk discovery), but very limited time to react
- Some advance planning to prepare contingency options
- Two successful tests!



Summary

- Another case study exposing the fallacy of “build to print:”
  - Flight chute nearly identical in design and construction but..
    - Requirements creep impacted design, manufacturing, and test
    - Internal and external activities exposed multiple unknown unknowns
    - Heritage broadcloth material no longer available



- More time spent on unplanned activities than planned ones:
  - Why? Not many flights of supersonic parachutes (N≈20)
    - every new flight can expose unknown unknowns
    - any chute failure induces lots of questions
  - Initial schedule well margined to accommodate unplanned effort

- High confidence in InSight parachute:
  - Parachute broadcloth tested more extensively then any mission since Viking
  - Flight lot chute tested subsonically to >2x the flight limit load
  - Retain very strong heritage basis for successful supersonic deployment on Mars