



THE CHALLENGES OF RE-STARTING AND OPERATING AN INHERITED NON- FUNCTIONAL FACILITY FOR GROUND SEGMENT TESTING

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Assignment

- Re-start a non-functional facility late in the test schedule, without an established budget, with little expertise with static testing, and to have it ready on time so as to not impact the Mars Science Laboratory (MSL) spacecraft and rover launch date.



Purpose of Static Load Testing

- Despite the best efforts at design and analysis, as we all know, physical testing is required to insure that the test article meets requirements such as strength, stiffness, coupled loads, etc.
- This is particularly true for spacecraft components that must be designed to be as light as possible.



The Starting Point for our Effort

- Steel I-beam test tower and enclosing building
- Old equipment of unknown condition
- Limited documentation
- Although experienced in other areas of testing, the co-authors of this paper had no previous experience with static load testing



Fig. 1a Looking up 40 feet to top of test tower



Fig. 1b Building enclosing test tower



Inherited Equipment



Fig. 2a Hydraulic load controller



Fig. 2b Hydraulic cylinders

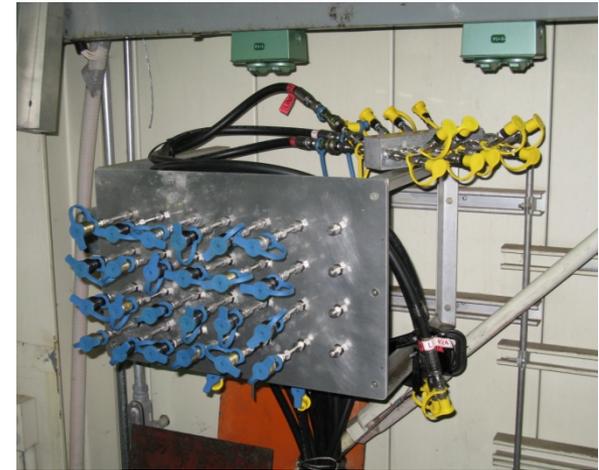


Fig. 2c Bulkhead panel and return manifold



New Equipment



Fig. 3a Hydraulic power unit (pump)

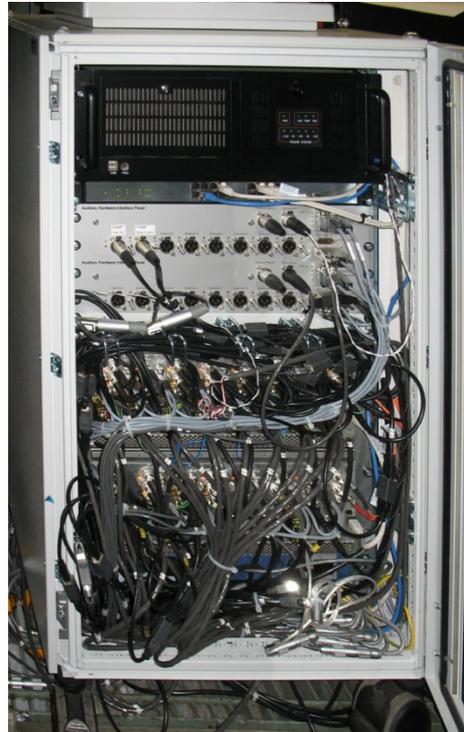


Fig. 3b Digital controller

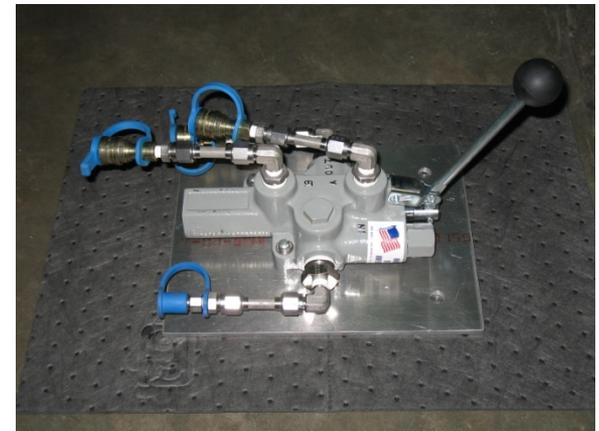


Fig. 3c Directional control valve

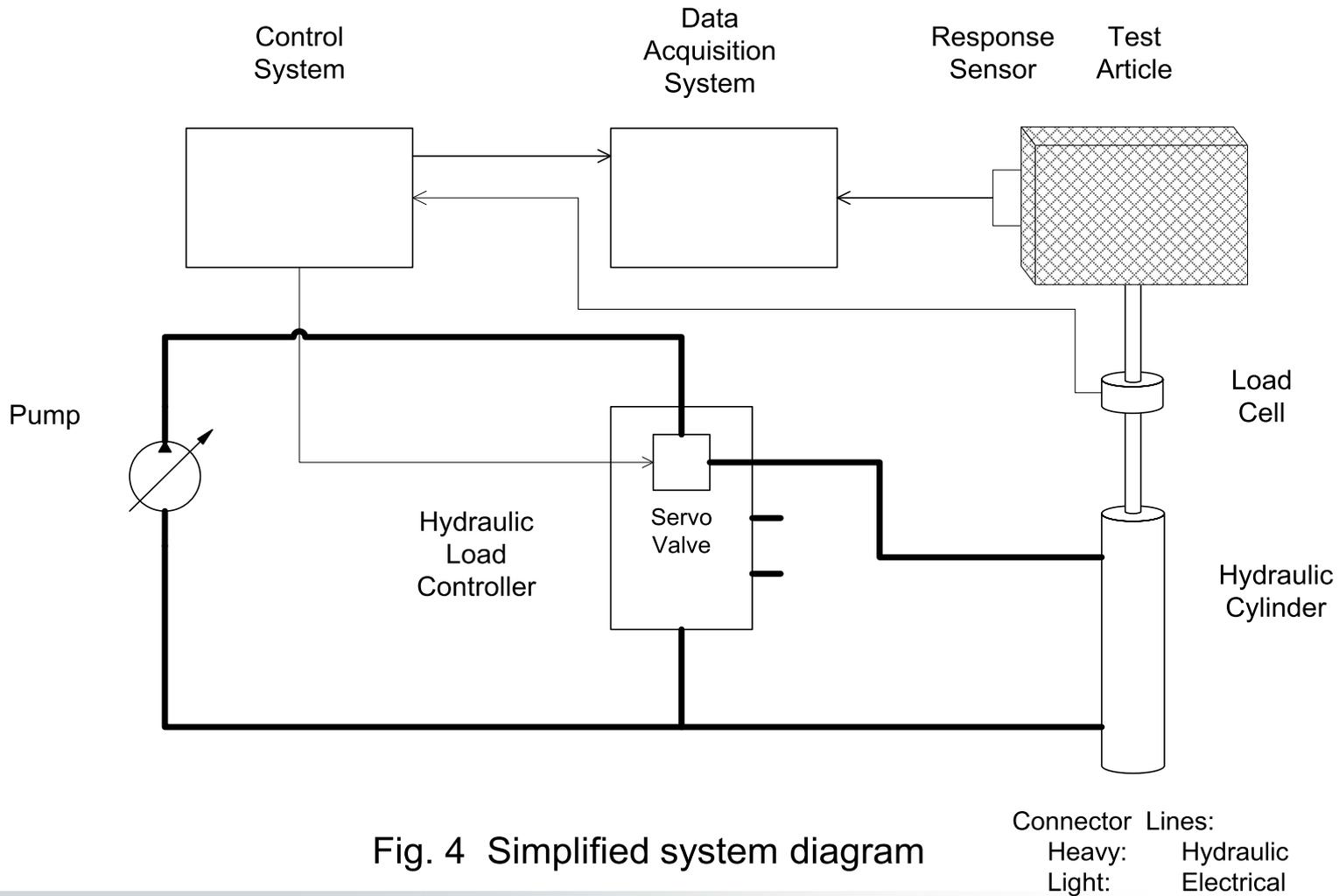


Fig. 4 Simplified system diagram



Saving Money (or not)

The costs of using old equipment may exceed those of purchasing and using new equipment.

- Effort required to establish condition of equipment
- Effort required to locate documentation (which may take longer if it no longer exists)
- Costs associated with creation of new documentation if old documentation does not exist
- Costs associated with refurbishment of equipment
- Costs associated with verification testing of refurbished equipment
- Older equipment may not fully meet functional requirements/"desirements"



Avoid the Costs of Solving Non-Problems

(The Saga of the Hoses)

- Customer: “What if the hydraulic cylinders leak internally?”
- Customer requested larger hydraulic lines
- Later, cylinders were checked for piston seal leaks
- Did we choose the best solution?



Customer Education and Management of Expectations

- Limited experience of customers
- Develop an introduction to static testing (e.g., Static Testing 101)
- Provide facility technical documentation
- Use standardized mechanical interface points
- Inattention to detail can degrade/damage the facility. (See Fig. 5)

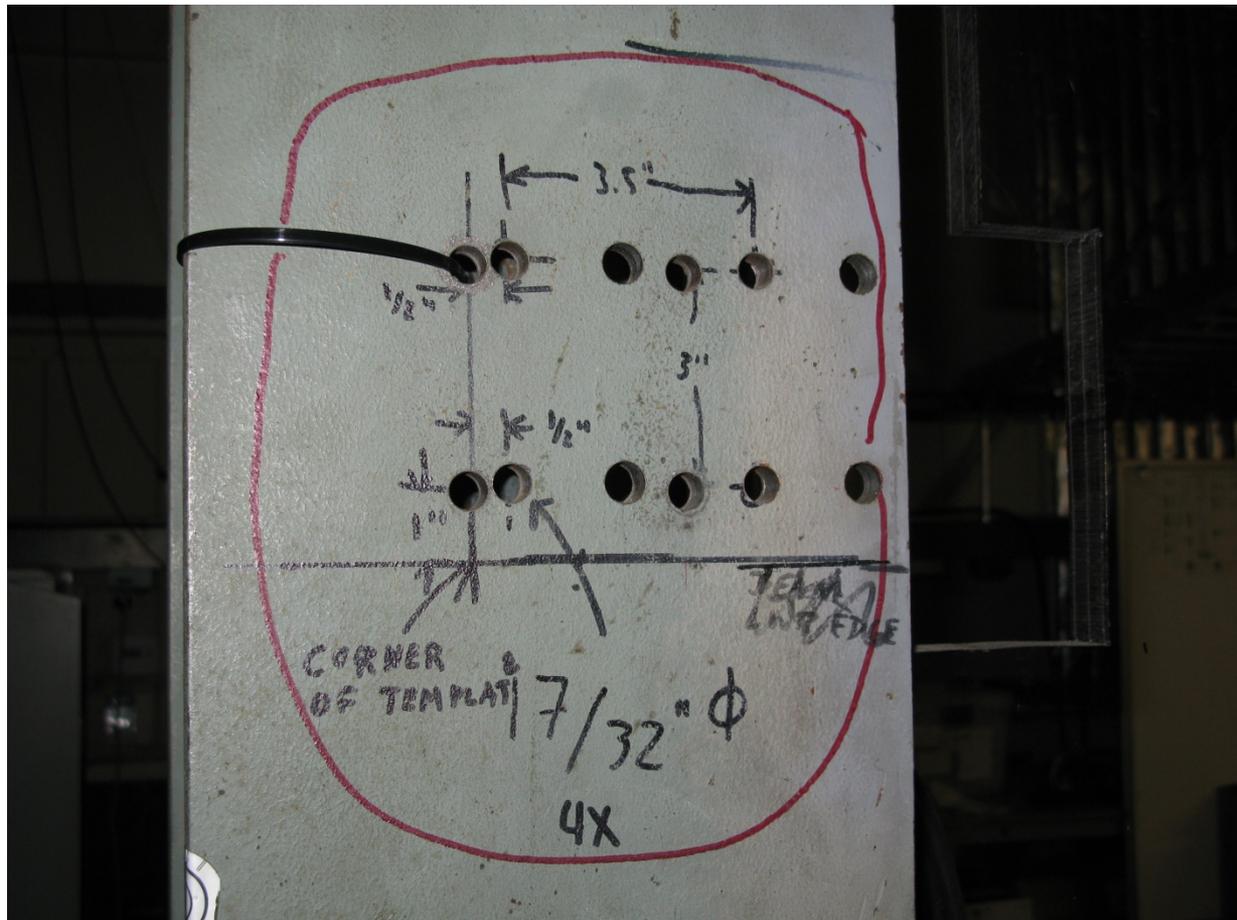


Fig. 5 Iron-enriched Swiss cheese
(Tower I-beam with holes resulting from multiple
location attempts by the customer)



Customer Education and Management of Expectations (cont'd)

- Use non-hazardous and reusable floor anchors

Floor Anchor Point Alternatives



Fig. 6a Have a nice trip!



Fig. 6b Studs cut off following test



Fig. 6c Reusable solution:
Threaded insert



End-to-End Verification and Testing

- Complex control systems may exhibit complex (and possibly unexpected) behavior.
- Overall system configuration verification
- Polarity reversals in closed-loop control systems -- going from bad to worse very quickly



End-to-End Verification and Testing (cont'd)

- The benefits of using a load cell simulator
- The importance of relationships between pressure, force, and raw sensor outputs
- Redundant emergency stop capabilities

End-to-End Test Frame

- The use of a test frame supported the verification of our overall configuration.

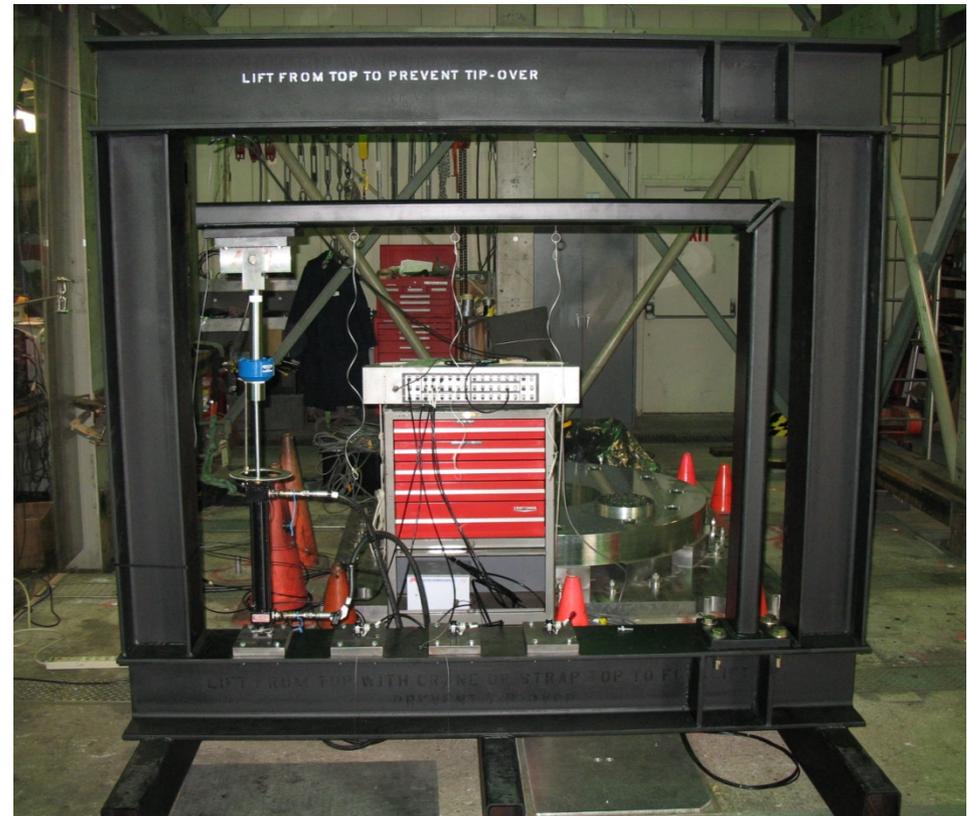


Fig. 7 Test frame



Additional Topics

- The importance of stable facility air temperature and a quiet environment for static testing.
- Hydraulic accessories for manual operations.
- Desirable features of an improved hydraulic load controller
- The importance of clearly defined roles and communications paths
- Technical and policy issues relating to the safety of personnel and equipment
- Consideration of alternatives to hydraulic actuators for future cleanroom environment testing
- Additional lessons learned



Operational at Last



Fig. 8 A test guest arrives



Conclusions

- The facility was returned to an operational state, all tests were completed successfully, and the facility can be used for future tests.
- One of the most valuable results from the tests were the lessons learned, many of which are applicable to other types of testing activities.
- It was observed that test organizations are more likely to have the incentive to record and preserve these valuable lessons learned since this information can assist in the successful and economical completion of future tests.



Questions?