



Additive Manufacturing of a Wind Tunnel Force Balance

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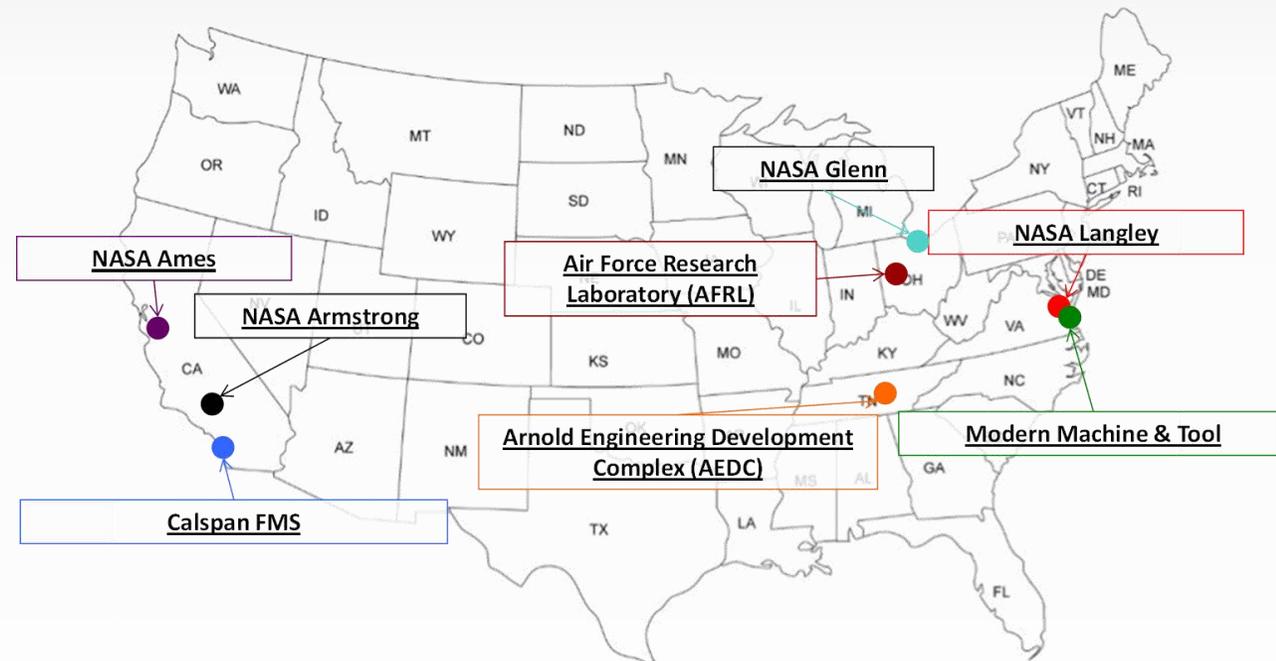
Rapid+TCT

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National Force Measurement Technology Capability

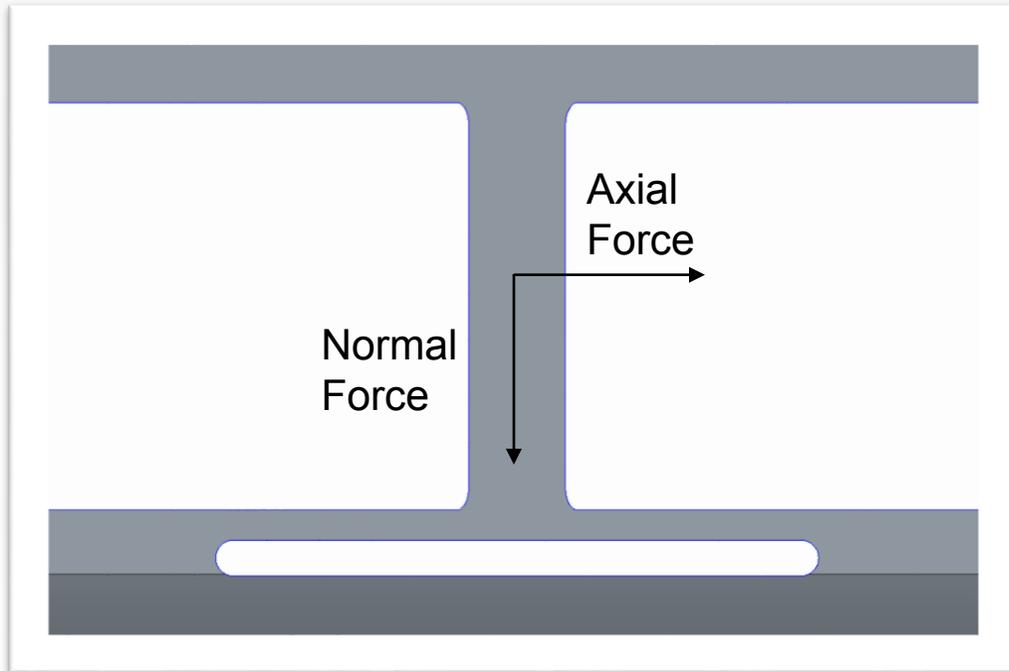


- Subject matter expertise in force and strain measurements.
- Responsible for NASA Aeronautics' ground test (wind tunnel) capabilities.
- Collaborate with DoD, industry, and academic partners.
- Provide operational support.
- Conduct research to advance force measurement capabilities.

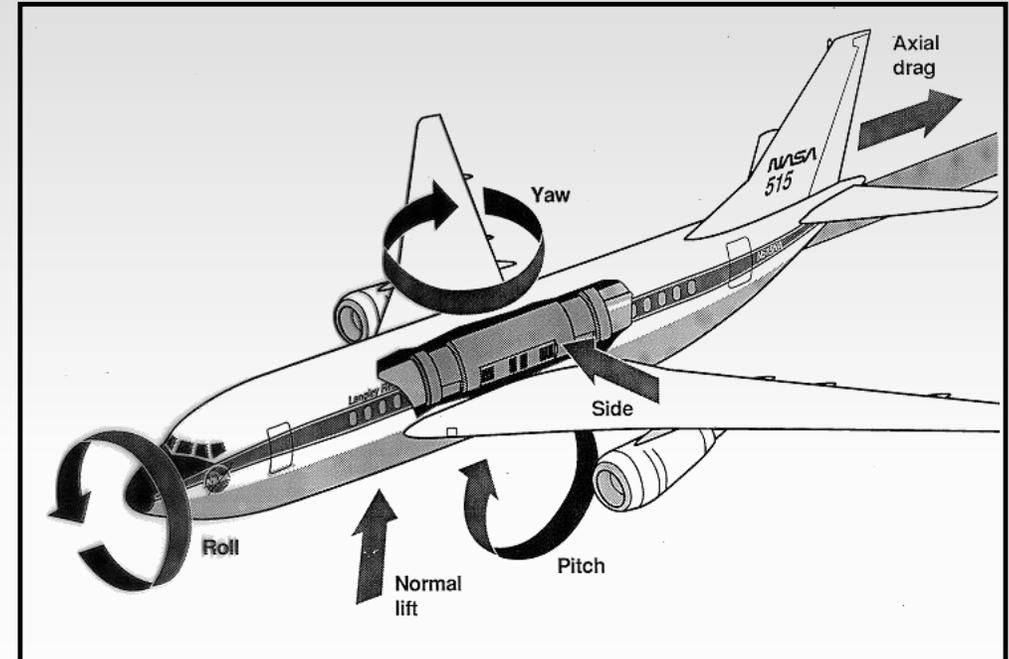


What is a force balance?

- Six component force transducer.
- Structural link between model and tunnel support hardware.



Axial force spring element.



Balances role in a wind tunnel test.

- Combination of many spring elements.
- Designed to isolate forces and moments.

What materials are used and why?



Material	E (psi x 10 ⁻⁶)	σ_y (psi x 10 ⁻³)	Hysteresis*
250 maraging steel	27	245	8
BeCu 25	17	170	8
6061-T6	10	40	4

*Scale from 1 (less desirable)
to 10 (more desirable)

*Perry, C.C., Starr, J.E., Weidner, J.R. (1992). *Strain Gage Users' Handbook*. Hannah, R.L., Reed, S.E. (Eds.). Bethel, CT: Elsevier Science Publishes Ltd. & Society for Experimental Mechanics.

Manufacturing Evolution

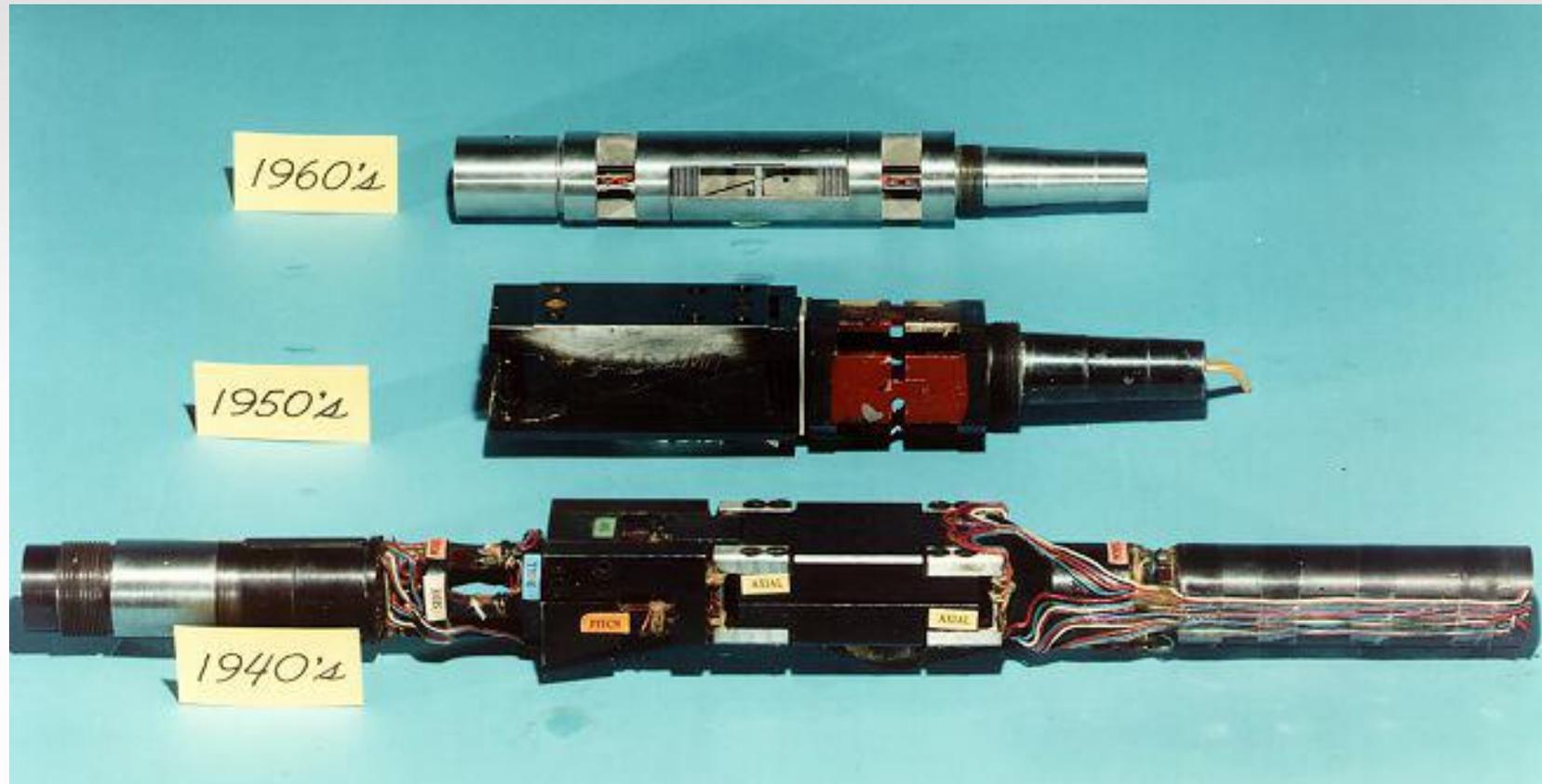
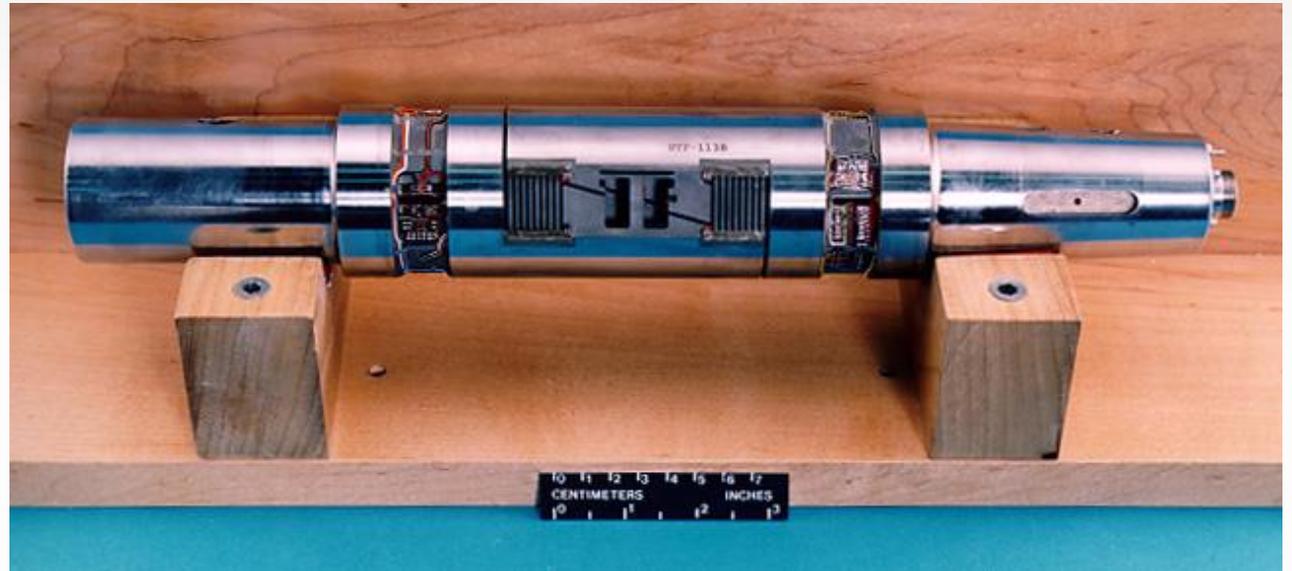


Photo illustrating how new manufacturing technologies have impacted force balance design through the decades.

Opportunities with AM

- Average balance manufacture time \approx 410 days*.
- Why?
 - Single piece thus a serial process.
 - Plunge EDM for many features.
 - Gage fits on front and rear ends.



Conventionally machined force balance.

*D. Cahill, F. Steinle and S. Richardson, "Evaluation of Wind Tunnel Internal Force Balances from Seven Vendors," AIAA Aerospace Sciences Meeting and Exhibit, pp. 1-10, 2004.

Cantilever Test Beams

- Powder based SLM printer at Langley.
- Material: 316L because of availability.



Test setup.



Two AM cantilever test beams.

- Gage area polished and gages installed.
- Cantilever beam type loading.
- AM beams were not as repeatable as conventionally machined beams.
- Overall, results were satisfactory.

DoD SBIR: AM of a Force Balance

- Phase I SBIR in 2012.
- Awarded to Morris Technologies*.
- Material: 15-5 PH.
- Direct metal laser melting used.
- Several prototype balances produced.
- Morris* acquired by GE* in 2012.



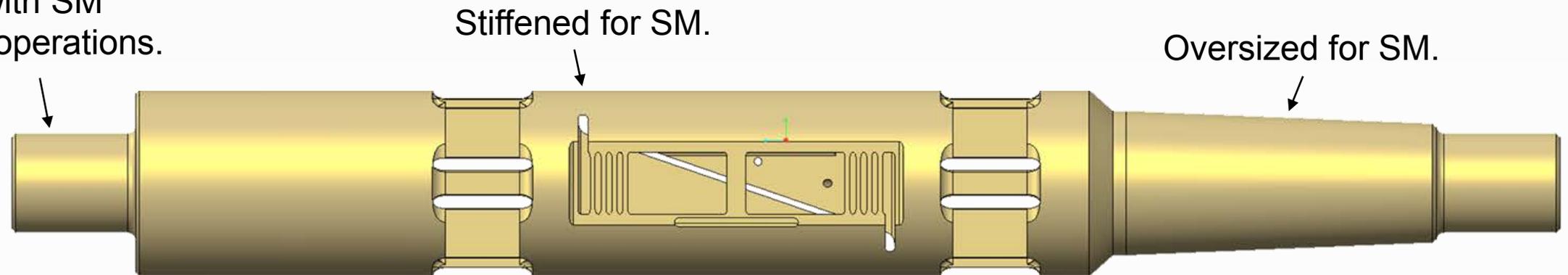
AM force balance produced by Morris Technologies*.

Collaboration: GE Additive Development Center*



- Follow on to SBIR effort.
- Objective: fabricate a balance using AM that we are manufacturing conventionally.
- Material: CoCr.
- Balance modified to accommodate AM processes.
- Secondary machining (SM) will be necessary.

Assist with SM turning operations.



1 cm

Design of force balance intended for AM.

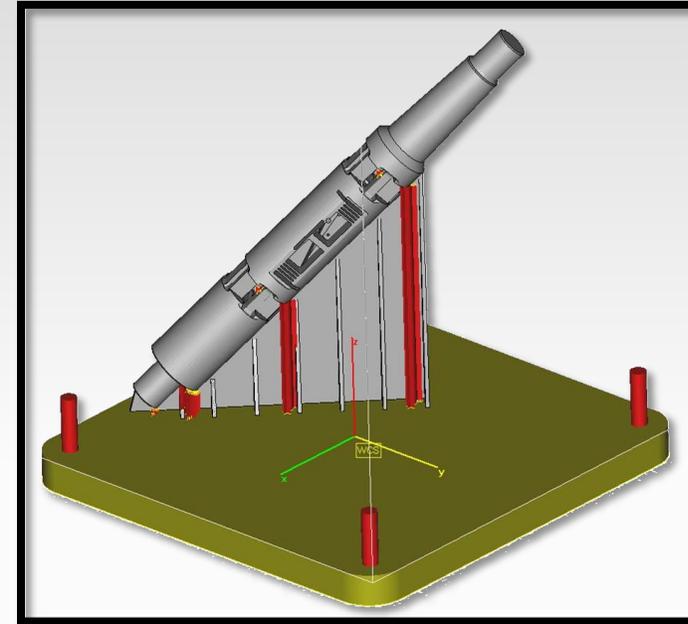
*Does not imply or constitute an endorsement by the United States Government.

Parallel Effort at Langley

- Powder based SLM printer at Langley.
- Material: CoCr.
- First model setup:
 - 45° balance orientation
 - Solid supports on 2/3 of balance



Photo of balance out of printer.



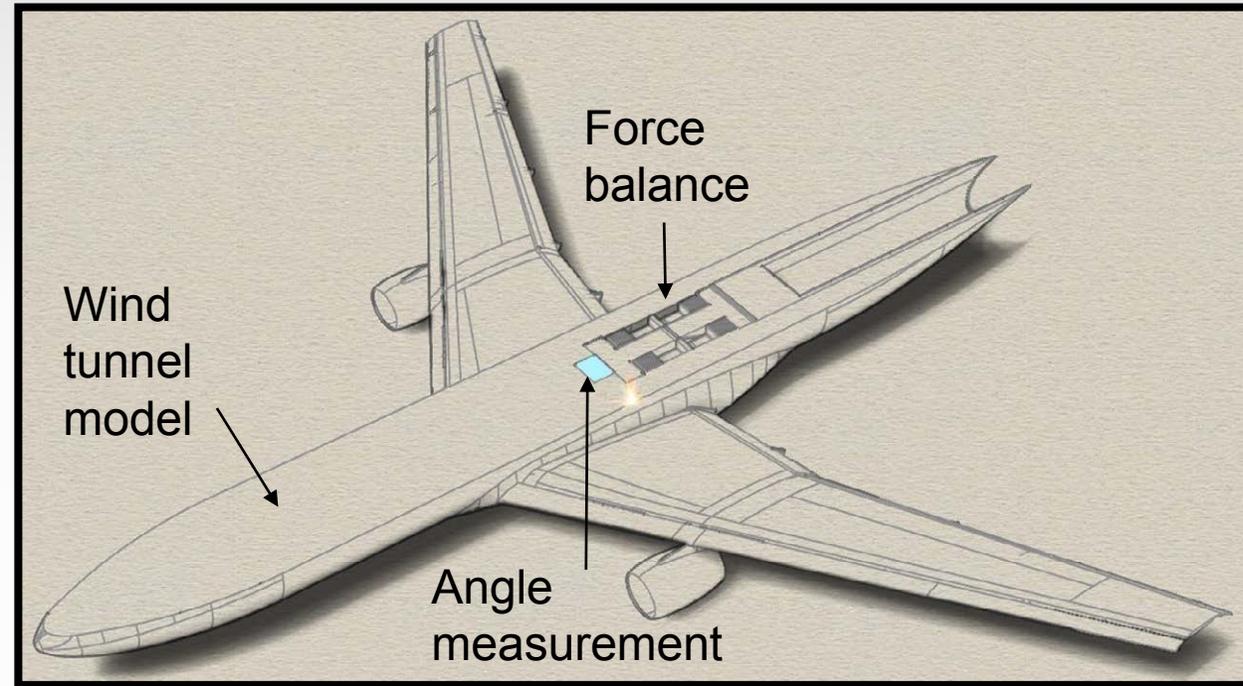
Layout of balance in AM software.

- All balance features printed to completion.
- No significant warping of balance.
- Heat treatments prior to secondary machining.

Long Term Vision



- Integrate wind tunnel model and measurement system fabrication.
- Integrate model and measurement system design teams.
- Re-think how wind tunnel models are designed and instrumented.
- Accelerate time from concept to test.



Conceptual drawing of wind tunnel model with integrated measurement systems mid-print.



Summary

- What we are looking for from manufacturing partners:
 - Materials with acceptable spring quality (materials like 15-5, maraging steels) and sufficient strength.
 - High build quality and repeatability → standards of practice, NDE methods.
 - Experience manufacturing structural components.
 - Minimal secondary machining.
- Potential benefits to the force balance community:
 - Increased design flexibility.
 - Faster manufacturing times.
 - Balances customized for individual tests.
 - Integration with models and other measurement systems.