Jet Propulsion Laboratory
California Institute of Technology

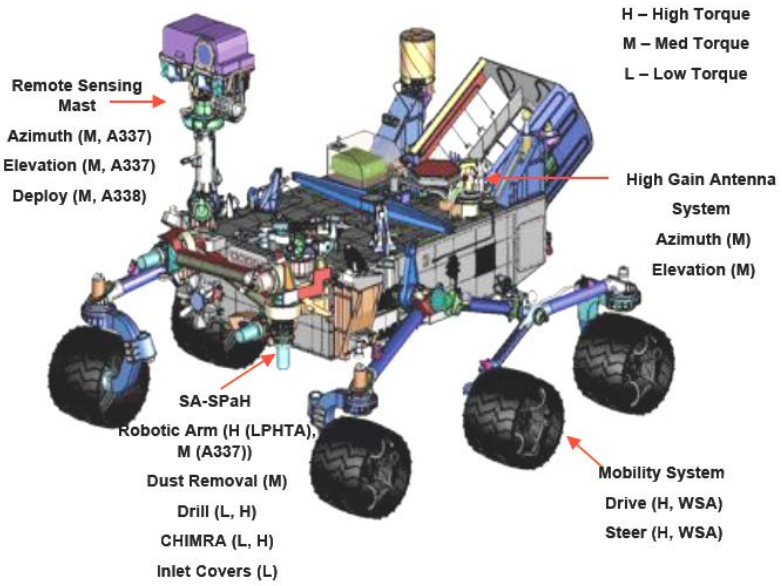
Fabrication and Property Development for a Functionally Graded Austenitic to Maraging Stainless Steel Component

R. Peter Dillon Ph.D., John Paul Borgonia, Peter Hosemann Ph.D., Andrew Shapiro-Scharlotta Ph.D., and Bryan W McEnerney Ph.D., February 16, 2015

Agenda

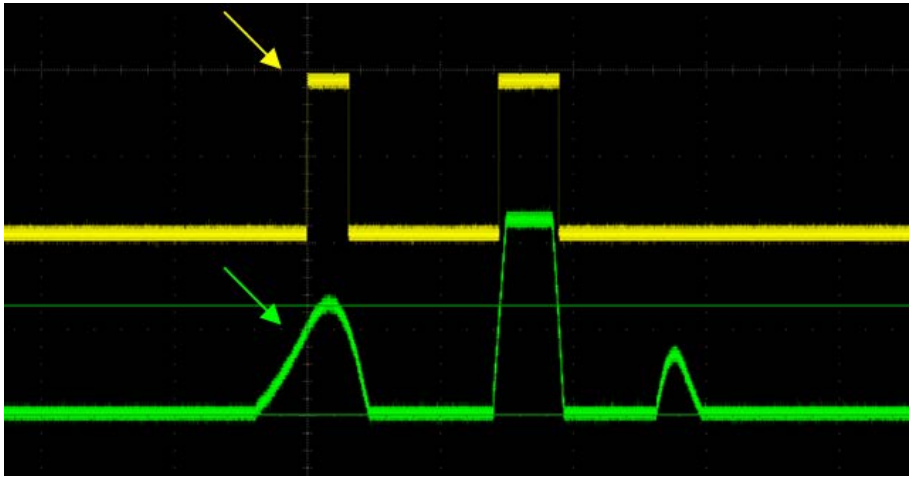
- Motivation for Functionally Graded Materials at JPL
- Mechanical Ground Support Equipment (MGSE) Test Article
  - Fabrication
  - Characterization
  - Testing
- Full Scale Fabrication
- Conclusions
- Future Work

Motivation: Mars Rover Actuators



The Curiosity Rover (or Mars Science Laboratory (MSL)):

- There are 51 actuators on the rover
- Maraging steel shafts were used in the actuators
- Magnetic interactions between the motor, brake and encoder were observed
- The encoders can be magnetically sensitive



What if a non-magnetic material was used, but only in the vicinity of the encoder?

- MGSE shaft used to test magnetic interactions.
- C300: alloy currently used in actuator shafts
  - Keep in dynamic area for mechanical properties
- 316L: Austenitic SS alloy
  - Non-magnetic
  - Low martensite formation
- Fabricate posts (blanks) using laser deposition (LD)
  - -140/+325 Carpenter 316L
  - -100/+270 Carpenter Micro-Melt 1.2709 (C300)
- Machine MGSE from posts

MGSE Test Article

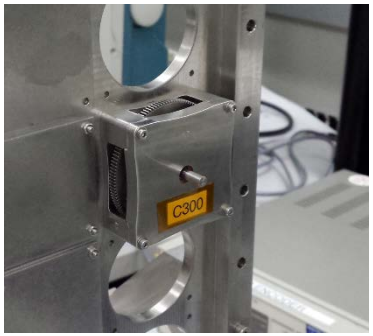
Materials Characterization of LD Posts

- Scanning Electon Microscopy
  - Grain size and morphology
- Energy-dispersive X-ray Spectroscopy (EDS)
  - Element mapping
- Electron Backscatter Diffraction (EBSD)
  - Crystal orientation and texturing

EBSD image showing orientation of various grains along the gradient

MGSE Magnetic Interaction Testing

- Shaft assembled in test gearbox
  - Assembly tested with drive and brake
  - Measure effect on encoder



MGSE Gearbox

Encoder

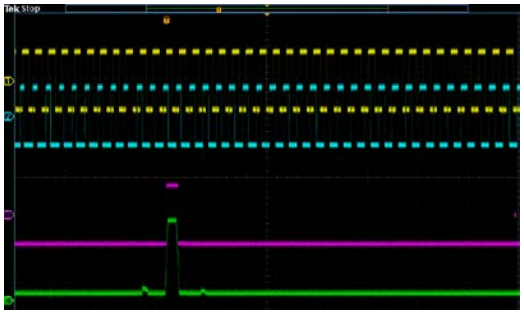
MGSE Test Bed

Magnetic brake

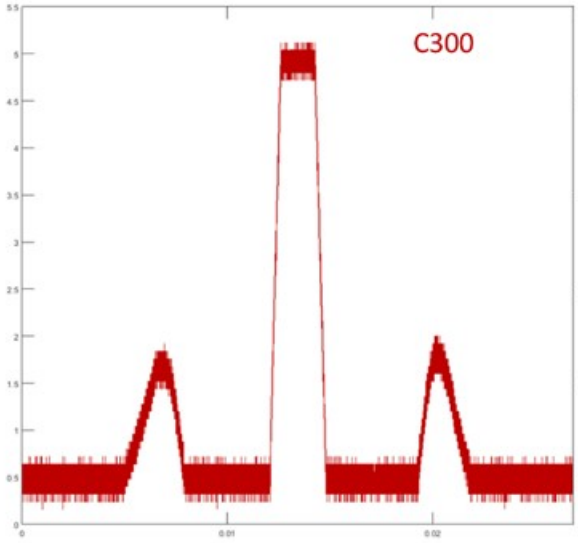
MGSE Magnetic Interaction Test Results

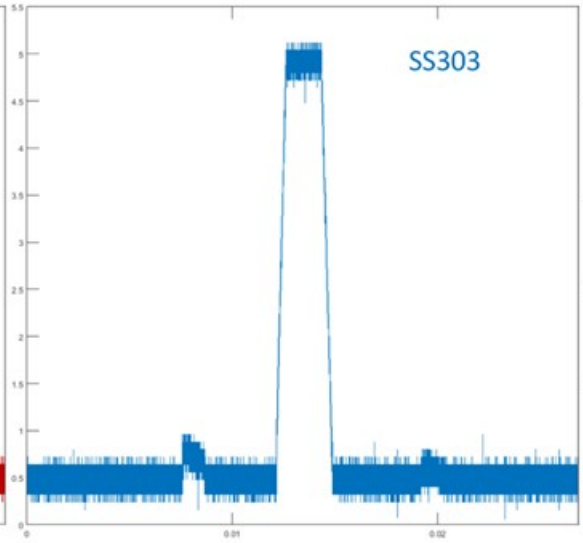
C300

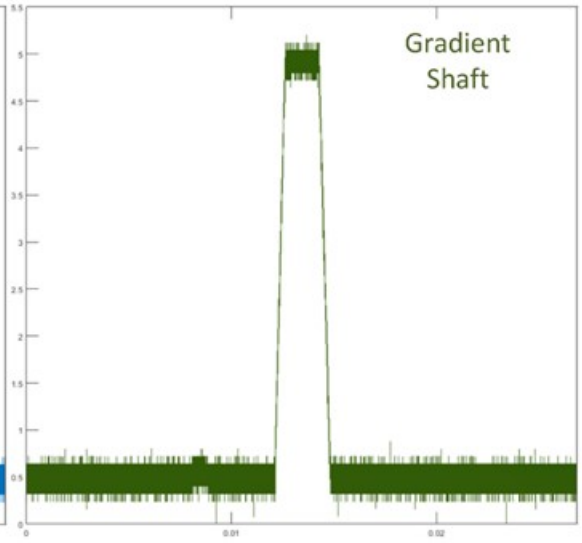
SS303



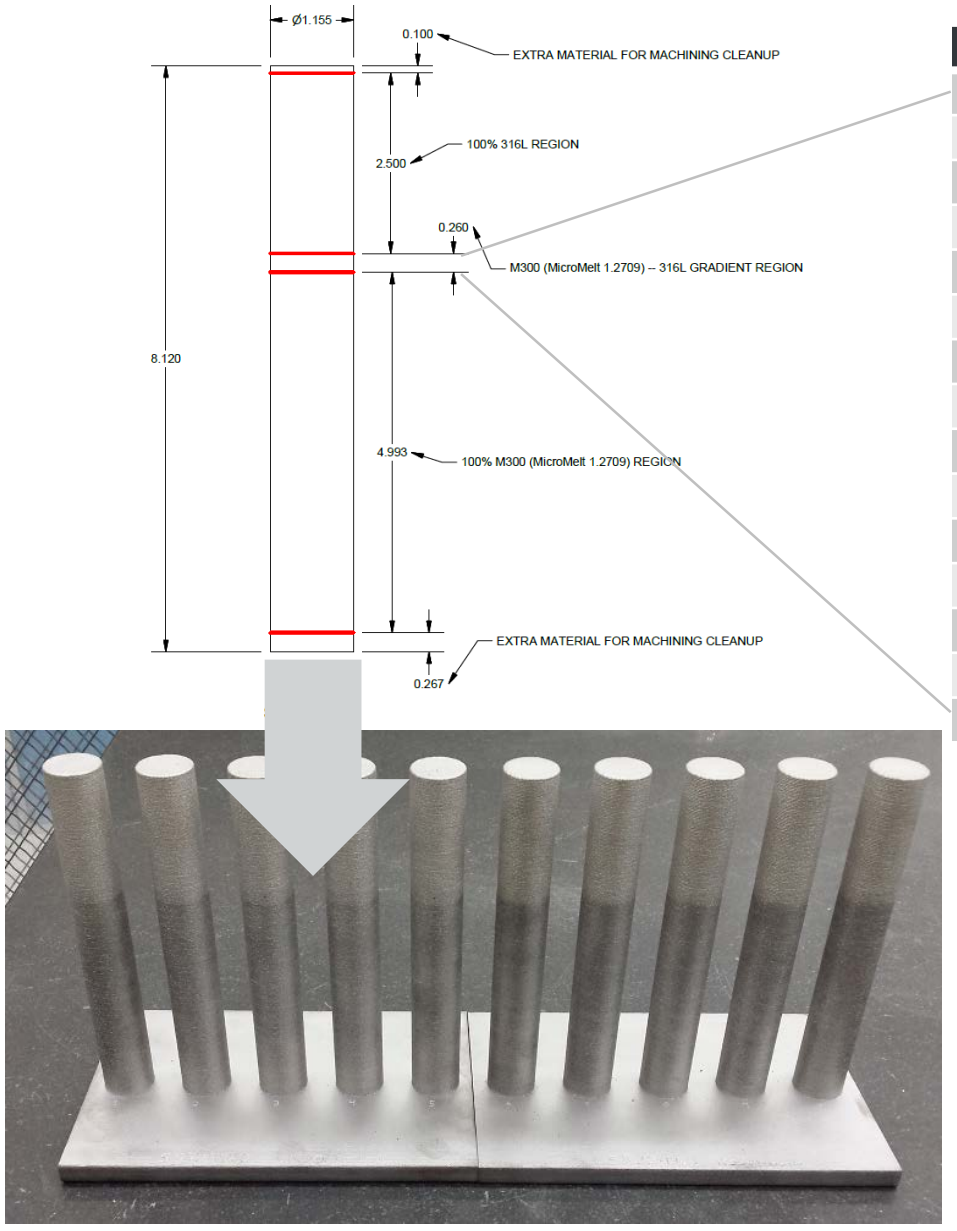
316L-C300 Gradient







Full Scale Fabrication of Blanks

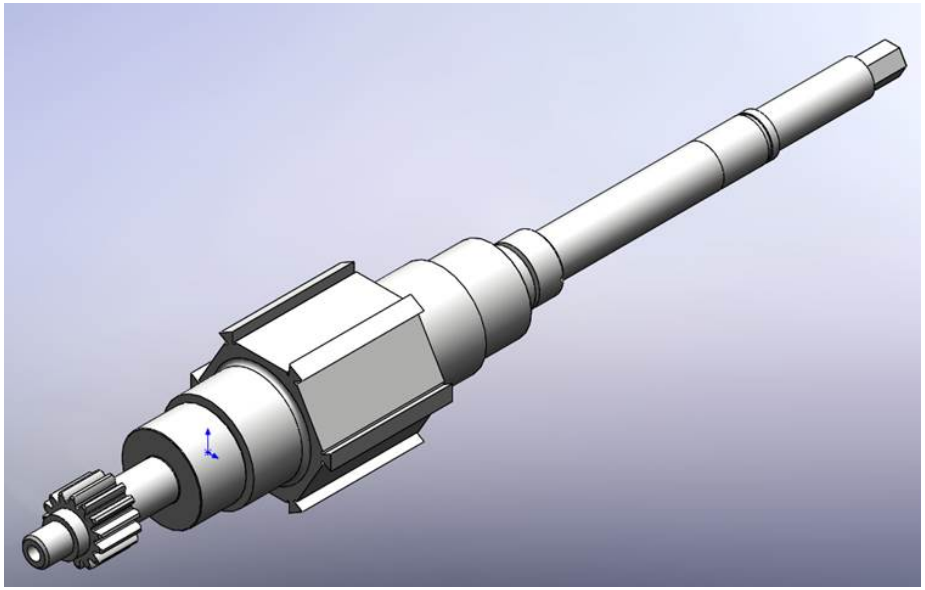


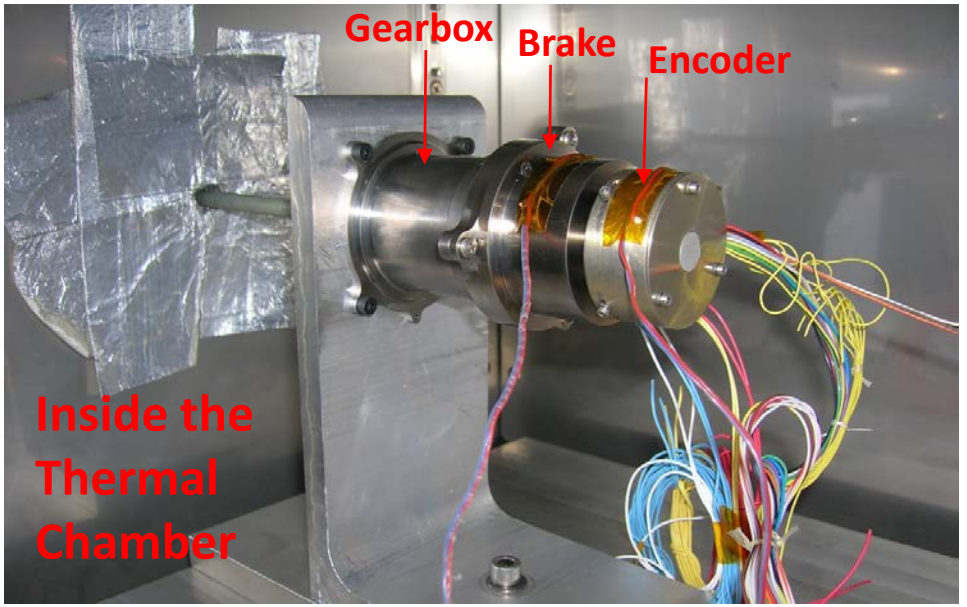
Start Layer	End Layer	Vol % C300	Vol % 316L
0	99	100.000	0.000
100	100	92.857	7.143
101	101	85.714	14.286
102	102	78.571	21.429
103	103	71.429	28.571
104	104	64.286	35.714
105	105	57.143	42.857
106	106	50.000	50.000
107	107	42.857	57.143
108	108	35.714	64.286
109	109	28.571	71.429
110	110	21.429	78.571
111	111	14.286	85.714
112	112	7.143	92.857
113	213	0.000	100.000

Selected fabrication parameters:
Nominal laser power: 990 W
Layer thickness: ~0.02 in
Hatch travel speed of 30 in/min

Future Work

- Complete Machining of Full Scale Gradient Shaft
- Integrate into actuator
- RT and thermal test of gradient alloy encoder shaft with actuator
  - Operate -90 to +105 °C
  - Survive: -135 to +120 °C
- Optimize heat treatment
- Complete mechanical testing
- Qualify for flight!



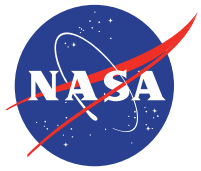


Conclusions

1. A gradient between C300 maraging steel and 316L stainless steel was successfully incorporated into an actuator component using laser deposition and traditional machining.
2. The magnetic properties were tailored in a monolithic structure through the use of additive manufacturing, specifically laser deposition.
3. The resultant magnetic properties appear to reduce, to an acceptable level, magnetic interactions between a motor, brake, and encoder.

Acknowledgements

- NASA Center Innovation Funds (CIF) and the JPL Office of the Chief Technologist (OCT)
- Ashley Reichardt, UC Berkeley
- Jong-ook Suh, Scott Roberts, Tien Nguyen, James Morcos, Gerald Lung, and Luis Dominguez, JPL
- RPM Innovations



Jet Propulsion Laboratory
California Institute of Technology

jpl.nasa.gov