Virtual Research Presentation Conference

Additive Manufacturing of Compliant Mechanisms for Deployable Structures

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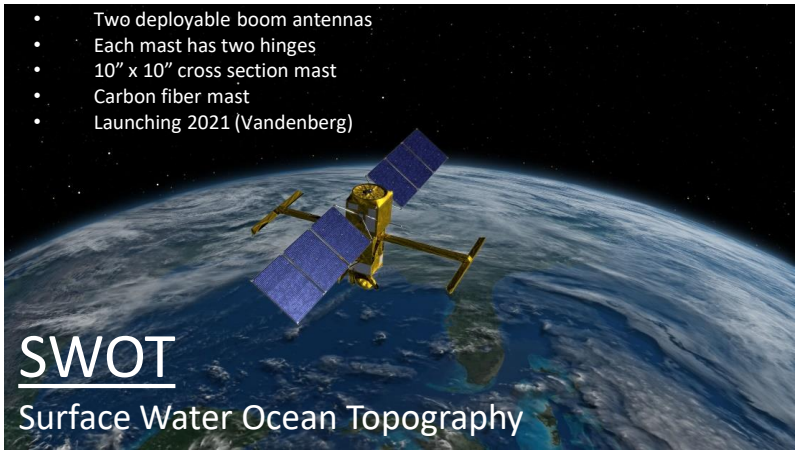
Cornelia Altenbuchner (347) Julian Rimoli (Georgia Tech)
Program: Spontaneous Concept

Jet Propulsion Laboratory
California Institute of Technology

Assigned Presentation #RPC-165

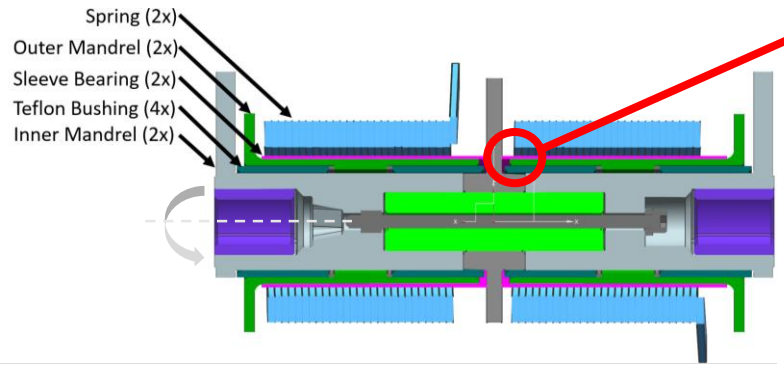
Introduction

Complex deployable structures have become common on JPL CubeSats (e.g. RainCube, MARCO, ISARA) and large-scale spacecraft (e.g. SMAP, SWOT, NISAR, Starshade). As new, ambitious missions are pursued, there is an increased need for more mass and volume efficient deployments (higher packing density). Over the same timeframe, additive manufacturing (AM) has enabled the fabrication of new forms of flight hardware. However, AM of compliant mechanisms has not been leveraged to design deployable space structures. AM of compliant mechanisms within deployable structures (e.g. antennas, solar panels, booms), could drastically lower part counts, create novel structural tuning methods, and design previously impossible geometries. Utilizing AM would therefore lead to deployable spacecraft elements with higher mass and volume efficiencies.



Problem Description

- Spring rectangular cross section cut into Teflon sleeve bearing below spring.
- Generating unacceptable foreign object debris
- Spring winding and cycling propagates failure
- Resulted in length and expensive hardware failure investigation

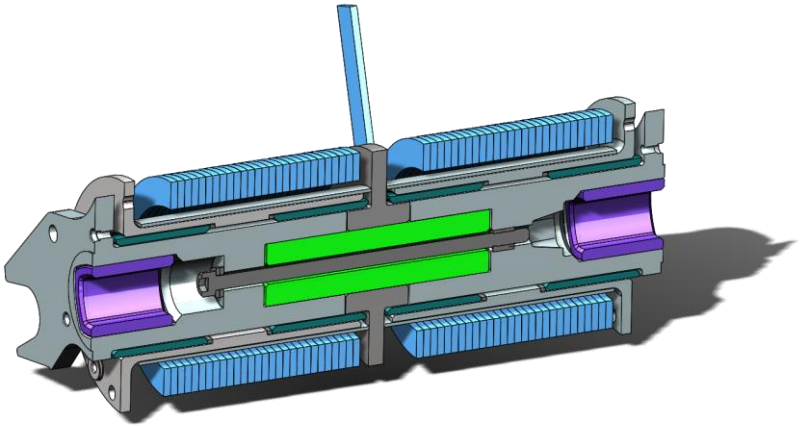


Methodology

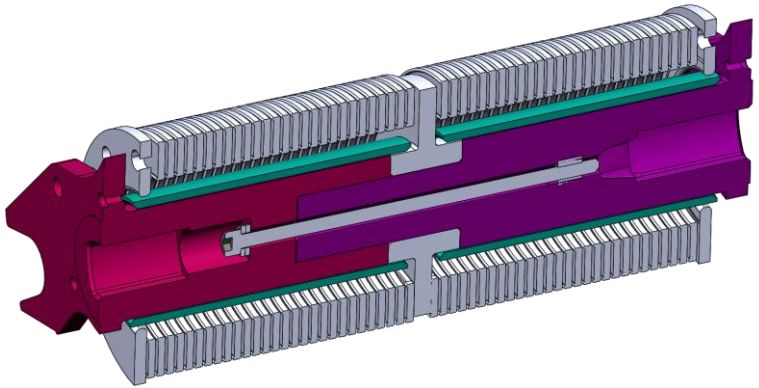
a) Demonstrate that additive manufacturing can be effectively used to improve performance within compliant mechanisms and torsional springs.

b) Demonstrate the additive manufacturing can be used to minimize part count in compliant mechanisms.

c) Further develop the state of the art within JPL for developing flight drawings for additive manufacturing.

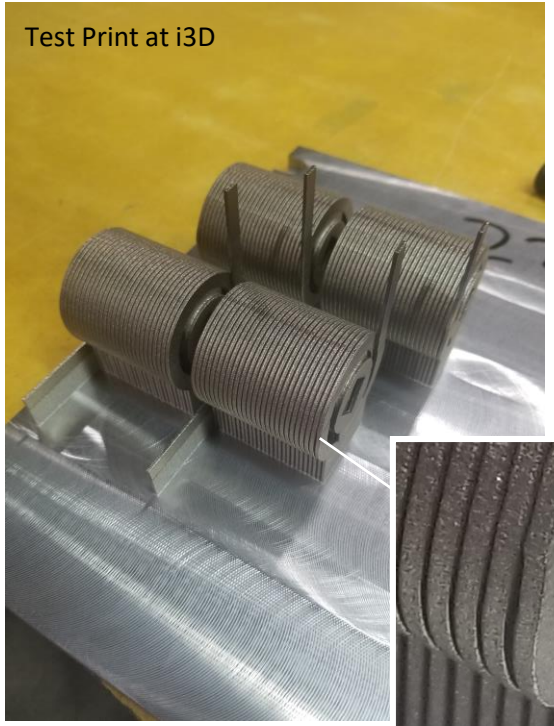


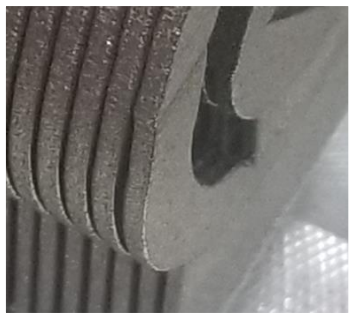
Original Mechanism (24 parts)

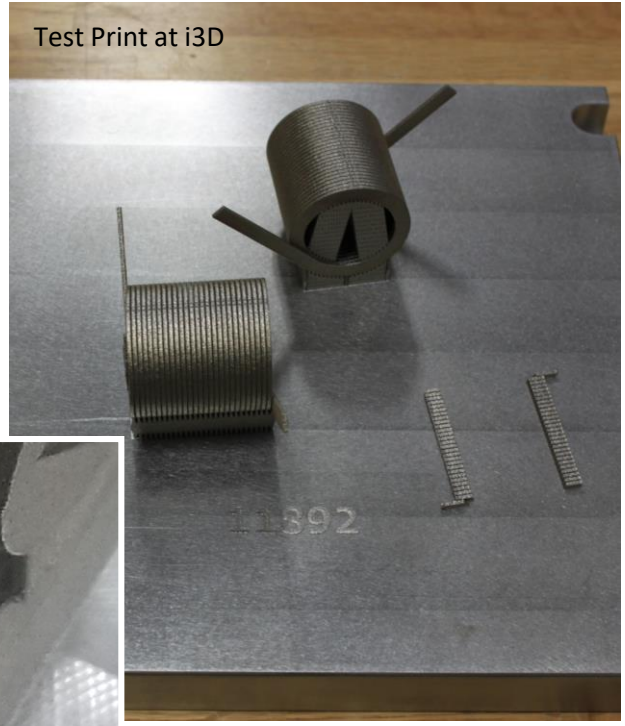


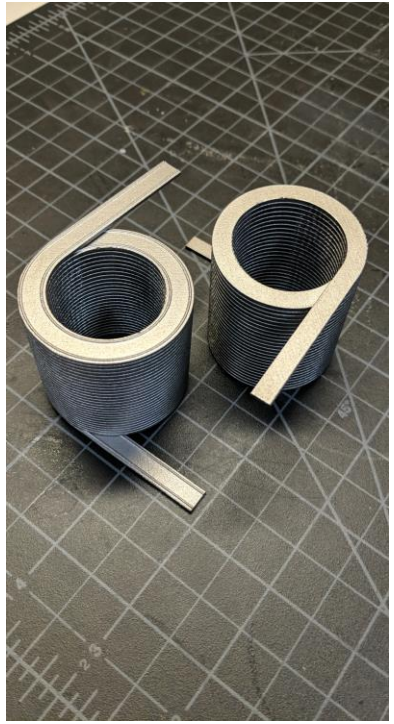
Spring performance enhancement (9 parts)

Results

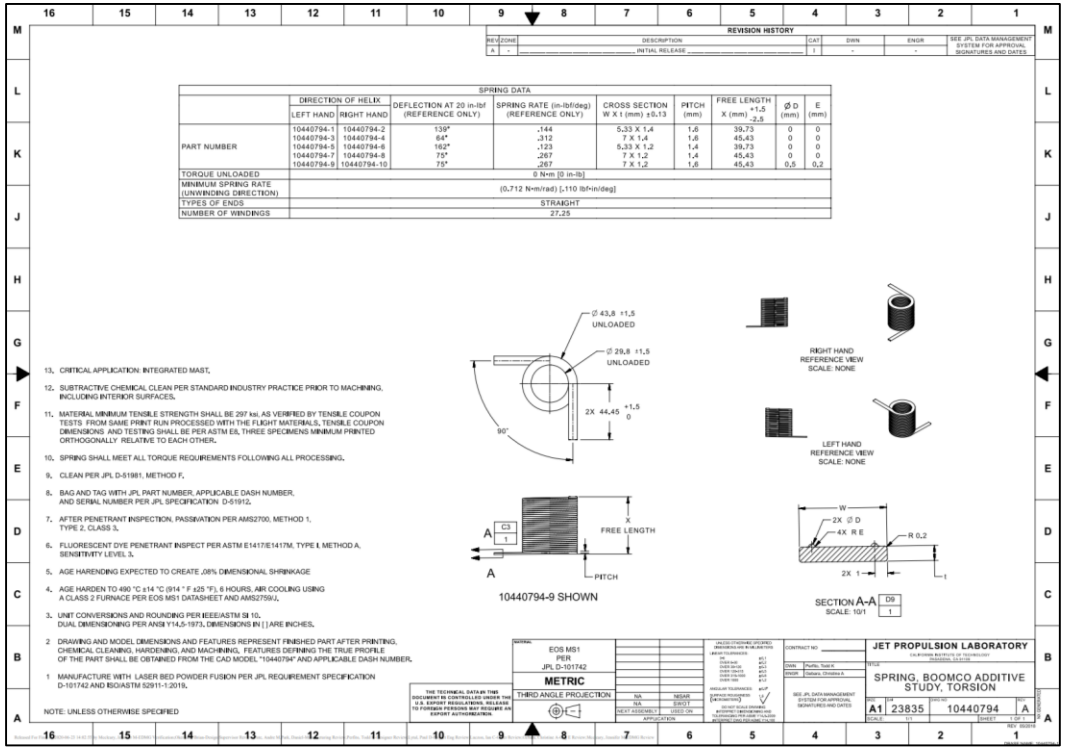








Cat 1 Drawing for Additive Manufacturing



REVISION HISTORY

REV	ZONE	DESCRIPTION	CAT	DWN	ENGR	SEE JPL DATA MANAGEMENT SYSTEM FOR APPROVAL SIGNATURES AND DATES
A	-	INITIAL RELEASE	1	-	-	

SPRING DATA

	DIRECTION OF HELIX		DEFLECTION AT 20 in-lbf (REFERENCE ONLY)	SPRING RATE (in-lbf/deg) (REFERENCE ONLY)	CROSS SECTION W X t (mm) ±0,13	PITCH (mm)	FREE LENGTH X (mm) +1,5 -2,5	Ø D (mm)	E (mm)
	LEFT HAND	RIGHT HAND							
PART NUMBER	10440794-1	10440794-2	139°	.144	5,33 X 1,4	1,6	39,73	0	0
	10440794-3	10440794-4	64°	.312	7 X 1,4	1,6	45,43	0	0
	10440794-5	10440794-6	162°	.123	5,33 X 1,2	1,4	39,73	0	0
	10440794-7	10440794-8	75°	.267	7 X 1,2	1,4	45,43	0	0
	10440794-9	10440794-10	75°	.267	7 X 1,2	1,6	45,43	0,5	0,2
TORQUE UNLOADED	0 N•m [0 in-lb]								
MINIMUM SPRING RATE (UNWINDING DIRECTION)	(0,712 N•m/rad) [.110 lbf•in/deg]								
TYPES OF ENDS	STRAIGHT								
NUMBER OF WINDINGS	27,25								

13. CRITICAL APPLICATION: INTEGRATED MAST.
12. SUBTRACTIVE CHEMICAL CLEAN PER STANDARD INDUSTRY PRACTICE PRIOR TO MACHINING, INCLUDING INTERIOR SURFACES.
11. MATERIAL MINIMUM TENSILE STRENGTH SHALL BE 297 ksi, AS VERIFIED BY TENSILE COUPON TESTS FROM SAME PRINT RUN PROCESSED WITH THE FLIGHT MATERIALS. TENSILE COUPON DIMENSIONS AND TESTING SHALL BE PER ASTM E8, THREE SPECIMENS MINIMUM PRINTED ORTHOGONALLY RELATIVE TO EACH OTHER.
10. SPRING SHALL MEET ALL TORQUE REQUIREMENTS FOLLOWING ALL PROCESSING.
9. CLEAN PER JPL D-51981, METHOD F.
8. BAG AND TAG WITH JPL PART NUMBER, APPLICABLE DASH NUMBER, AND SERIAL NUMBER PER JPL SPECIFICATION D-51912.
7. AFTER PENETRANT INSPECTION, PASSIVATION PER AMS2700, METHOD 1, TYPE 2, CLASS 3.
6. FLUORESCENT DYE PENETRANT INSPECT PER ASTM E1417/E1417M, TYPE II, METHOD A, SENSITIVITY LEVEL 3.
5. AGE HARENDING EXPECTED TO CREATE .08% DIMENSIONAL SHRINKAGE
4. AGE HARDEN TO 490 °C ±14 °C (914 ° F ±25 °F), 6 HOURS, AIR COOLING USING A CLASS 2 FURNACE PER EOS MS1 DATASHEET AND AMS2759/J.
3. UNIT CONVERSIONS AND ROUNDING PER IEEE/ASTM SI 10. DUAL DIMENSIONING PER ANSI Y14,5-1973, DIMENSIONS IN [ ] ARE INCHES.
2. DRAWING AND MODEL DIMENSIONS AND FEATURES REPRESENT FINISHED PART AFTER PRINTING, CHEMICAL CLEANING, HARDENING, AND MACHINING, FEATURES DEFINING THE TRUE PROFILE OF THE PART SHALL BE OBTAINED FROM THE CAD MODEL "10440794" AND APPLICABLE DASH NUMBER.
1. MANUFACTURE WITH LASER BED POWDER FUSION PER JPL REQUIREMENT SPECIFICATION D-101742 AND ISO/ASTM 52911-1:2019.

NOTE: UNLESS OTHERWISE SPECIFIED

Ø 43,8 ±1,5 UNLOADED
Ø 29,8 ±1,5 UNLOADED
2X 44,45 +1,5 0
90°
10440794-9 SHOWN

RIGHT HAND REFERENCE VIEW SCALE: NONE
LEFT HAND REFERENCE VIEW SCALE: NONE

FREE LENGTH
PITCH
C3
W
2X Ø D
4X R E
R 0,2
2X 1
SECTION A-A SCALE: 10/1

EOS MS1 PER JPL D-101742
METRIC
THIRD ANGLE PROJECTION

THE TECHNICAL DATA IN THIS DOCUMENT IS CONTROLLED UNDER THE U.S. EXPORT REGULATIONS. RELEASE TO FOREIGN PERSONS MAY REQUIRE AN EXPORT AUTHORIZATION.

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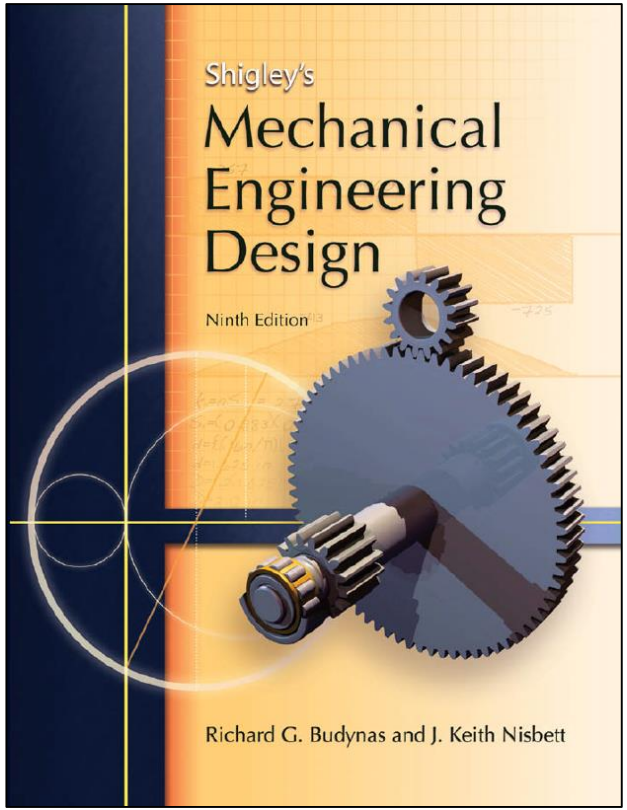
CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CA 91109

SPRING, BOOMCO ADDITIVE STUDY, TORSION

SIZE A1 | CAGE 23835 | DWG NO 10440794 | REV A | SHEET 1 OF 1

Publications and References




Mechanical Springs

by

A. M. Wahl

Westinghouse Electric & Manufacturing Company

First Edition

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