Phase I SBIR - Battery-Powered Process for Coating Telescope Mirrors in Space

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Battery-powered deposition unit for ground-based coating

Why Coat Mirrors in Space?

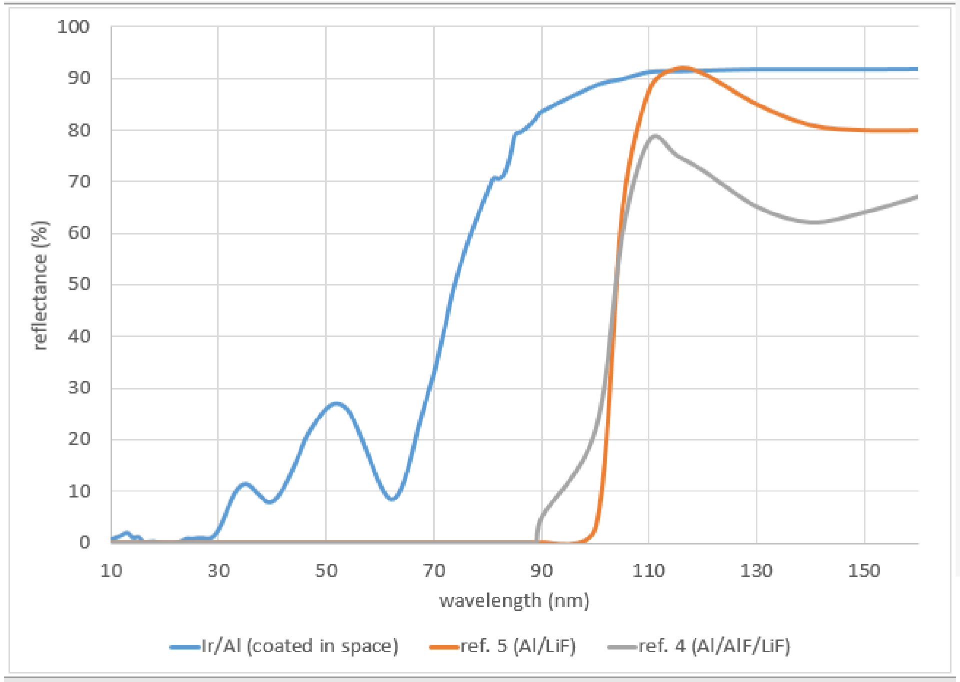
"…if the space-based coating technology was mastered the reward would be an increase in throughput for a 3-reflection optical system by an order of magnitude" – FUSE Lessons Learned, 2004.

- protected over-coats of fluorides such as MgF2 or LiF, absorb the energy below 120-nm

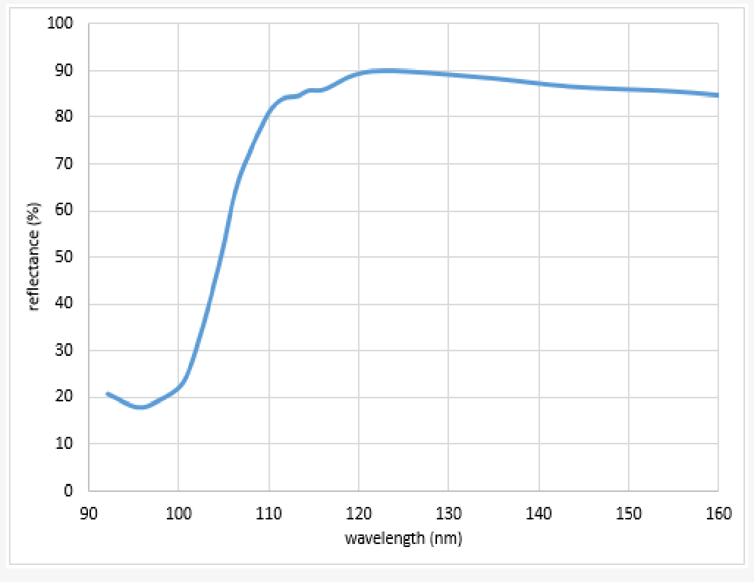
- without the protective fluoride, aluminum forms a natural oxide when in the atmosphere, which absorbs energy below ~180-nm.

- a bare aluminum coating made in space, could reflect energy down to 35-nm (currently, the spec for LUVOIR is 90-nm minimum)

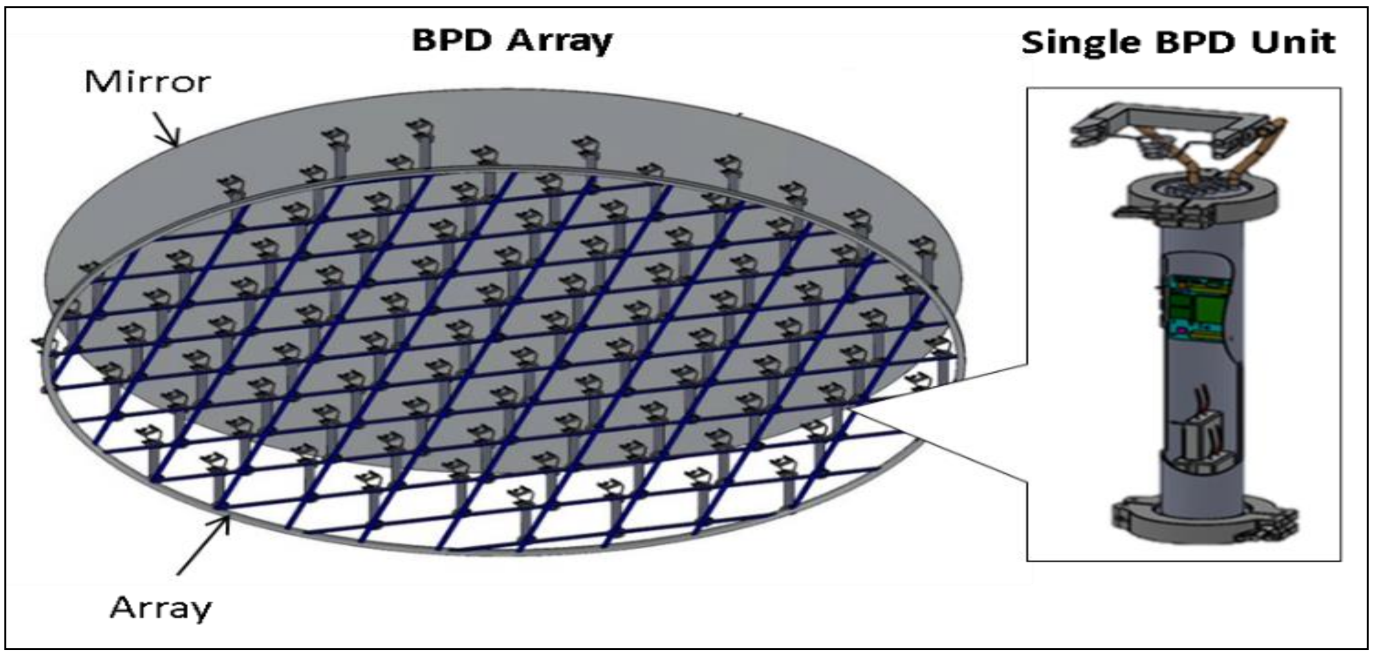
Why coat a mirror in space?



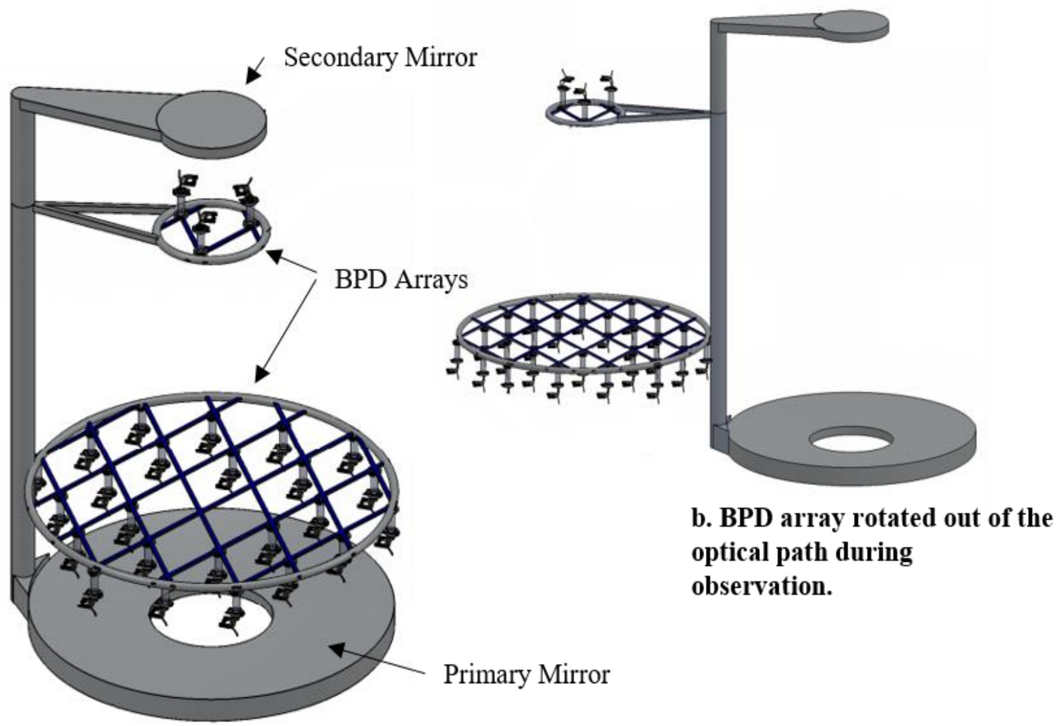
GSFC (2016):



Battery-powered filament evaporator, or "battery-powered deposition (BPD)"



Telescope designed for coating in space



b. BPD array rotated out of the optical path during observation.

a. BPD array in front of the primary and secondary mirrors during coating

Keys to demonstrating the feasibility of coating in space

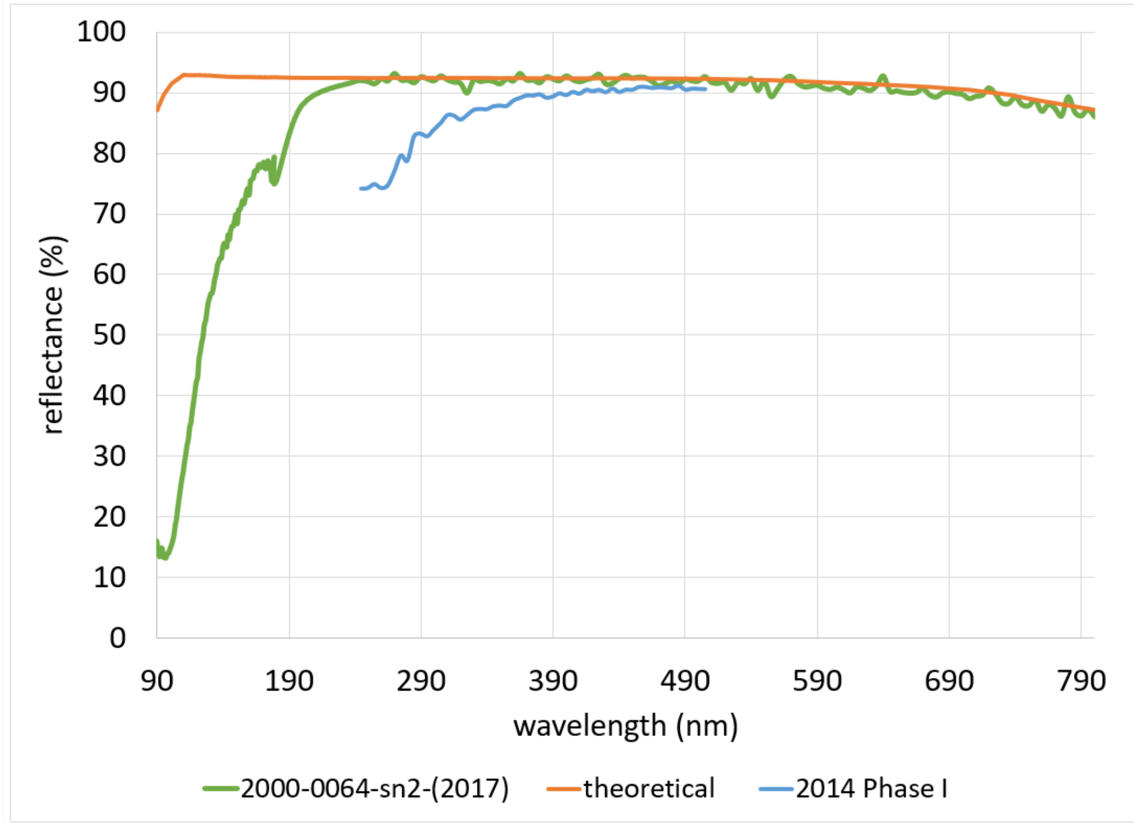
- Ability to generate high coating rates over large areas
  - Target is 100 to 400 A/sec
- Ability to control coating thickness errors
  - Target is +/- 1 nm RMS ➔ ~4-nm PTV ➔ +/- 5% for a 40-nm film
- Dealing with thermal issues
  - Temperature of the substrate during coating in space
  - Thermal-cycling of the batteries and warming them before use
- Design of the telescope and deployment of coating array

Reflectance as a function of deposition rate

Evaporation rate	200-nm (reflectance %)	400-nm (reflectance %)
40 (A/sec)	82.7	91
65 (A/sec)	87.6	91.5
125 (A/sec)	90.2	91.8

* Aluminum deposited at a background pressure of ~1x10^-6 torr

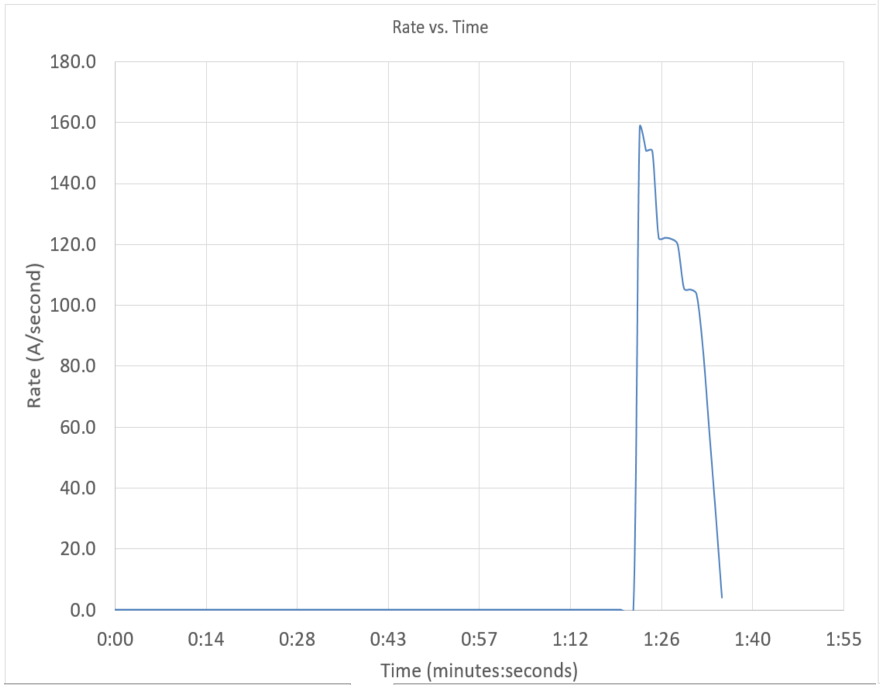
Reflectance results comparison

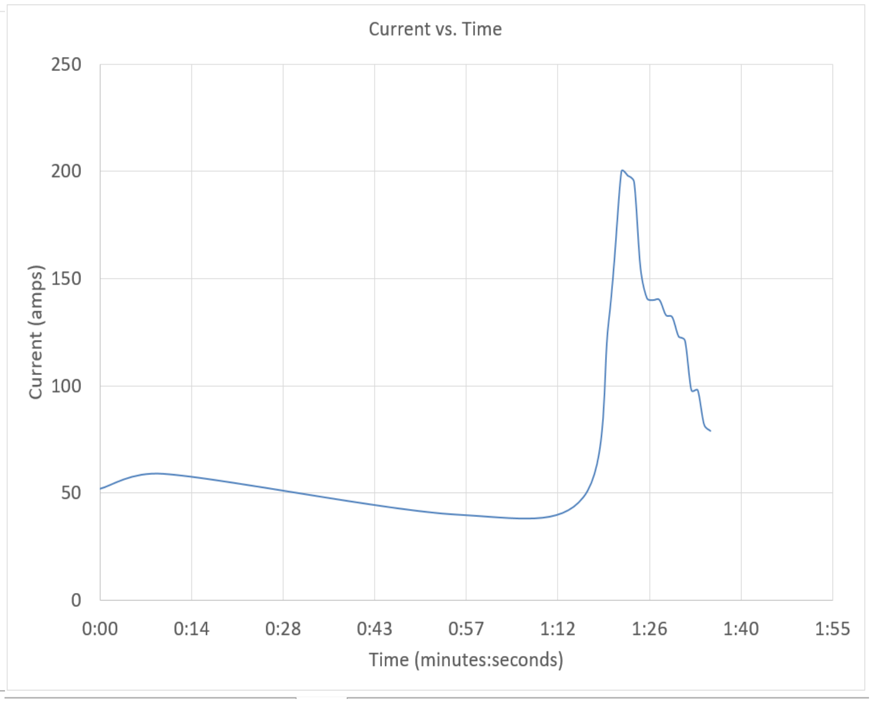


Note: ZeCoat 2017 results @ 80 A/sec
Al over-coated with AlF

Evaportion rate vs. Time

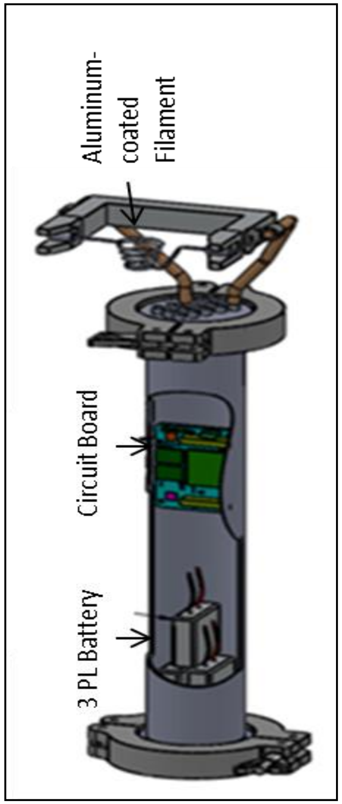
Current vs. Time

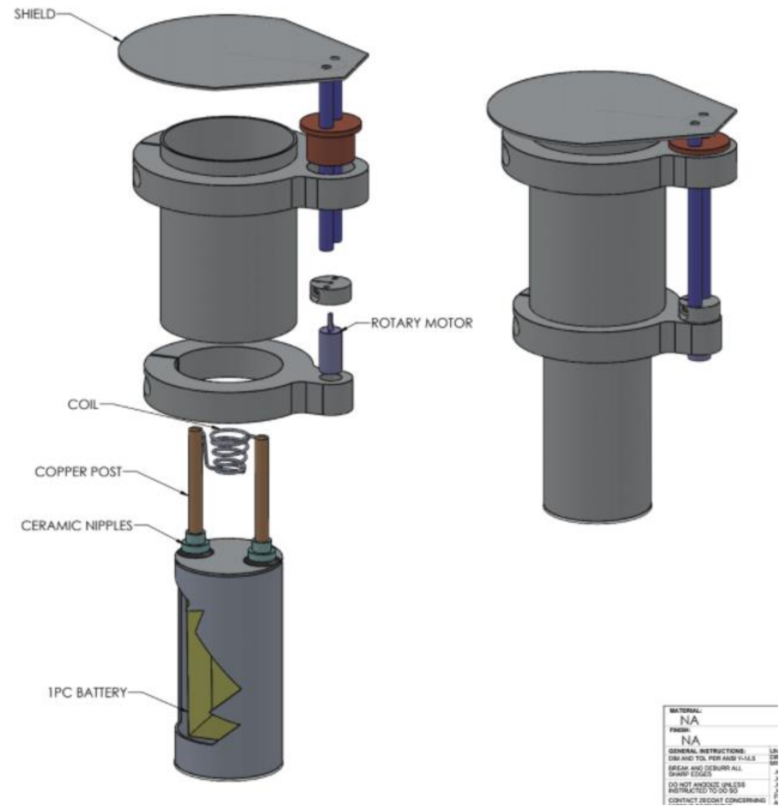




Battery-powered deposition

- Low voltage, high current (e.g, 7-volts and 200 amps, per source, 1400 watts)
- Many combined sources provide high evaporation rates (400+A/sec), higher UV reflectance, and less UV scatter
- Placing the power supply in close proximity to the evaporation filament means electrical losses are minimized


Aluminum-coated Filament
Circuit Board
3 PL Battery


SHIELD
ROTARY MOTOR
COIL
COPPER POST
CERAMIC NIPPLES
1PC BATTERY
MATERIAL:
NA
FINISH:
NA
GENERAL INSTRUCTIONS:

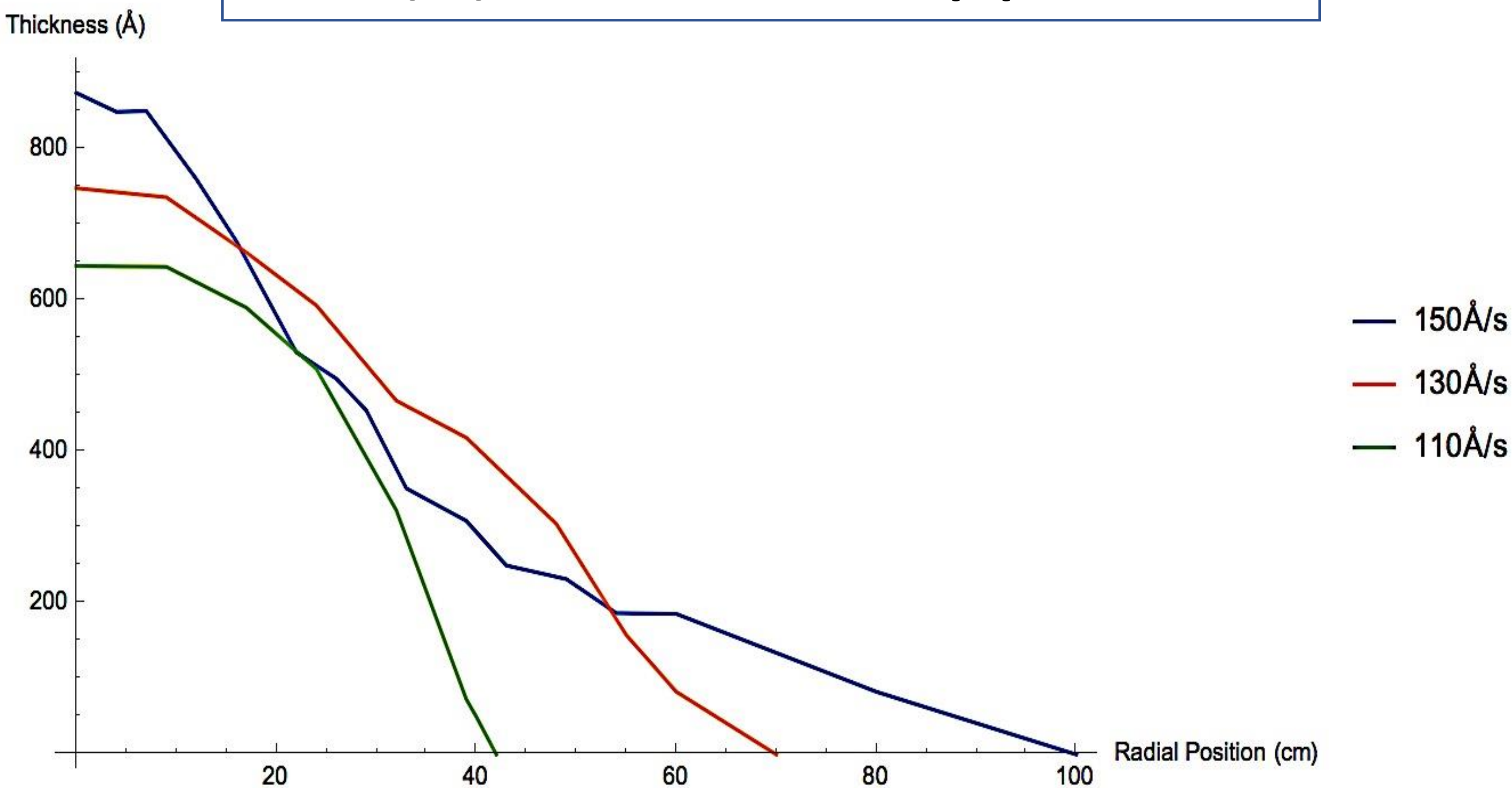
Coating thickness variation; experimental procedure:

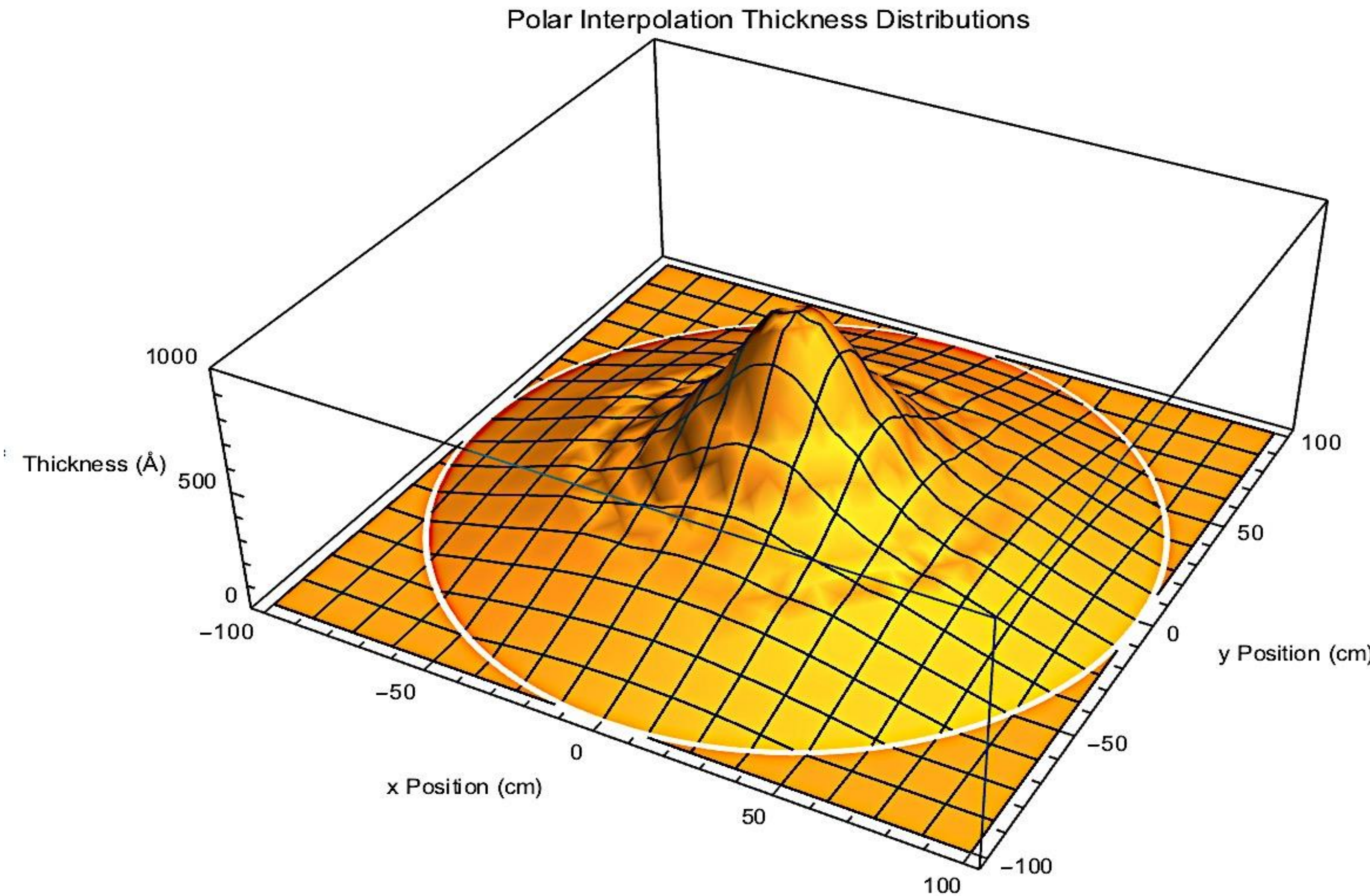
The coating thickness distribution for a single battery powered source was mapped using a stylus profilometer and with optical density.

(3) different plumes were created using masks

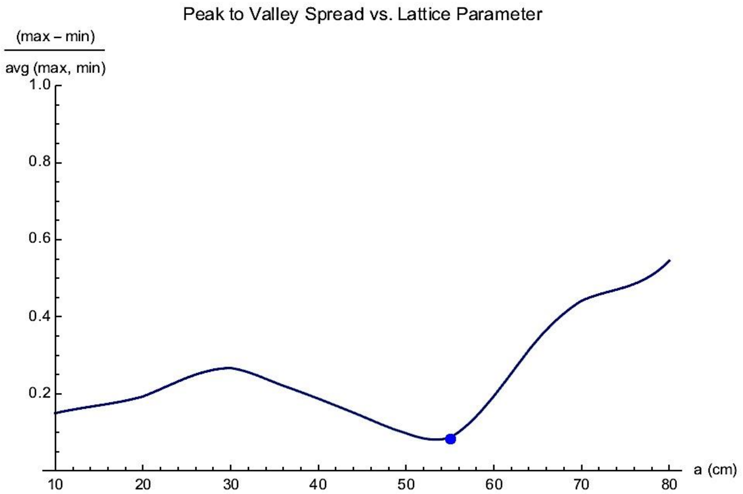
A computer simulation was developed to determine the optimum source spacing for a hexagonal array of (31) sources

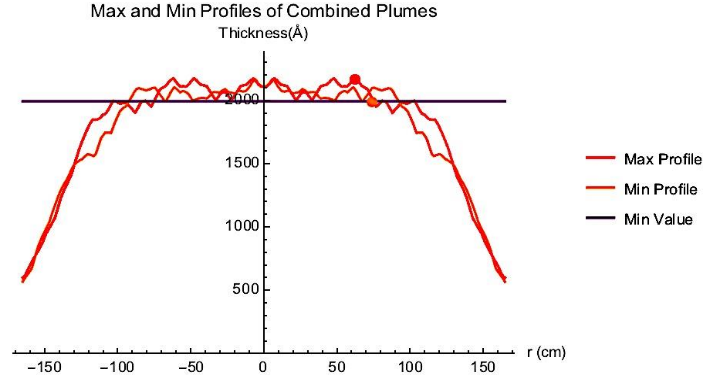
(3) Plumes mapped

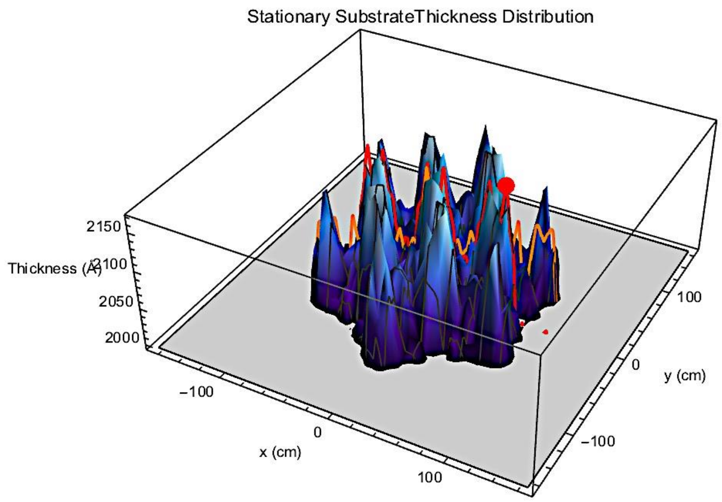


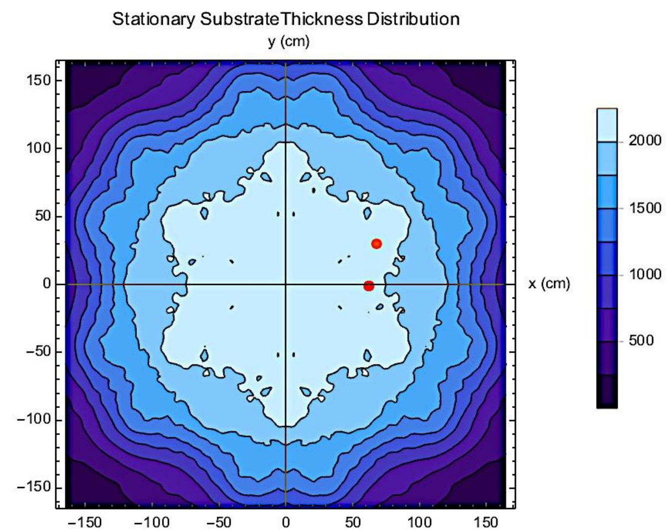

Polar Interpolation Thickness Distributions
1000
Thickness (Å)
500
0
−100
−50
0
x Position (cm)
50
100
100
50
0
y Position (cm)
−50
−100

Plume Type 1 – Unmasked, 150 A/sec

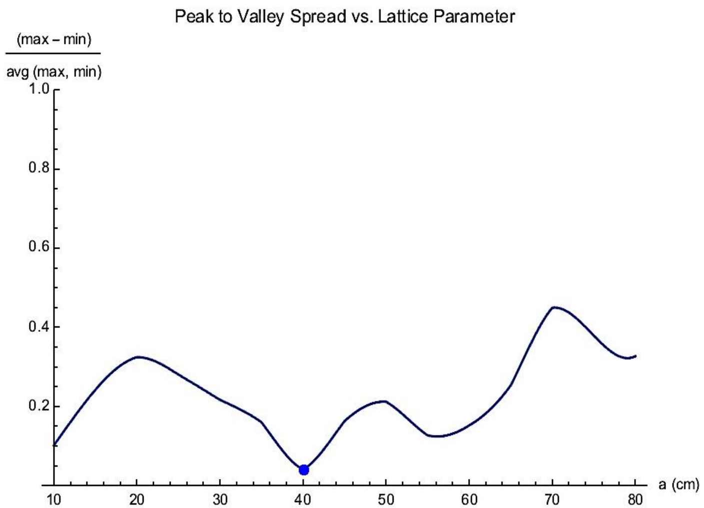


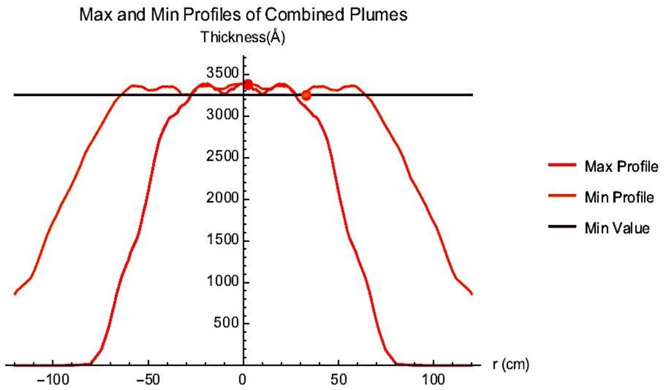


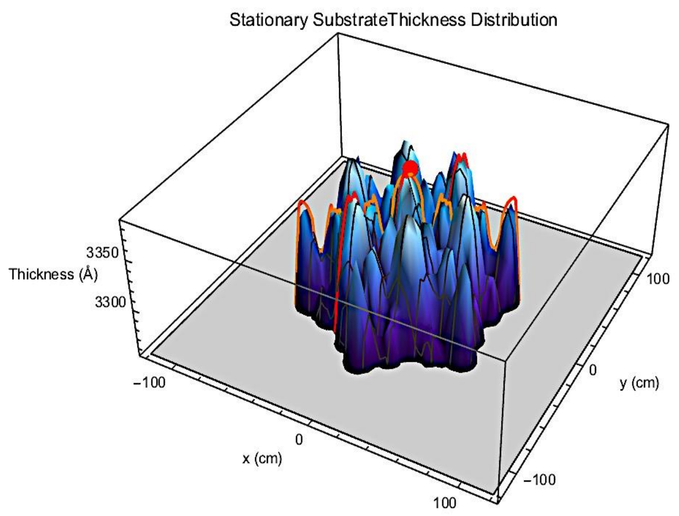


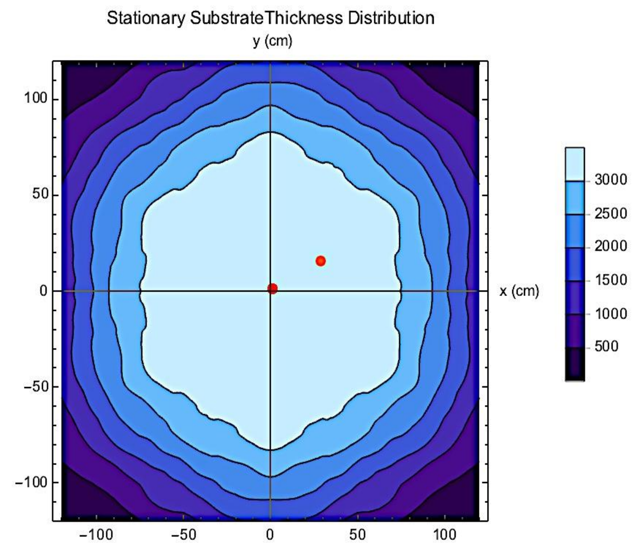


Plume Type 2 – Large hold mask, 130 A/sec

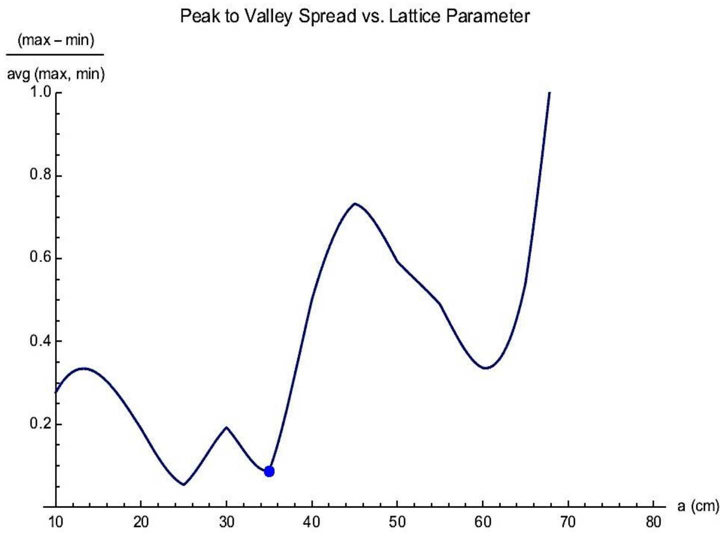


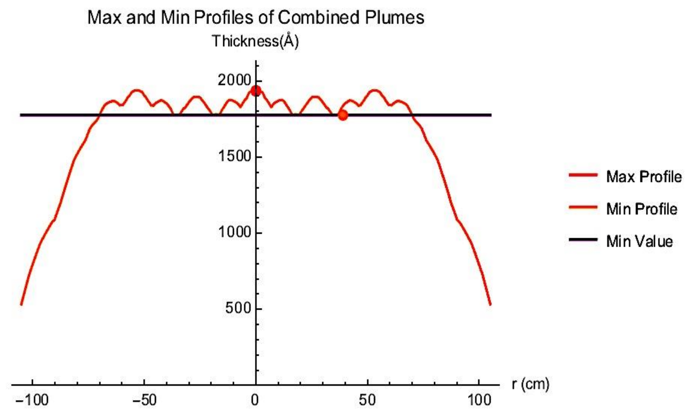


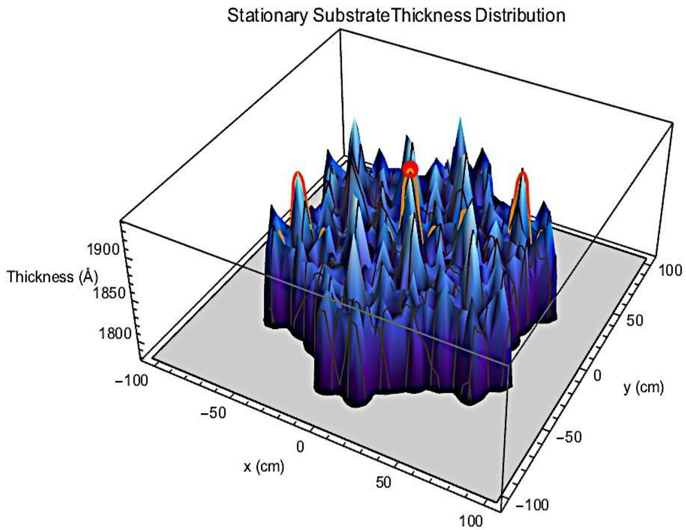


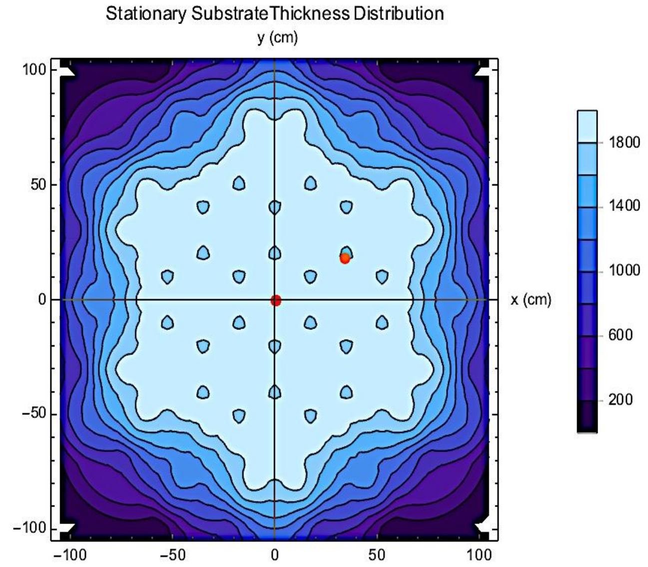


Plume Type 3 – Small hole mask, 110A/sec









Plume Modeling Results Summary

	Single Plume	Combined Plumes	Plume spacing	~ # plumes	coverage efficiency	PTV coating error	PTV (nm)	~RMS error for 40-nm coating
	Rate (A/sec)	Rate (A/sec)	(cm)	per m^2	(%)	(%)	(nm)	(nm)
unmasked (2015)	41	133	23	62	48	6.4	2.56	0.6
unmasked	150	523	55	10	53	10	4	0.9
large hole mask	130	566	40	15	64	4	1.6	0.4
small hole mask	110	317	35	20	64	10	4	0.9

Phase II Plan – Get as close as possible to TRL6 by the end of Phase II

- Miniaturize battery-powered deposition unit
- Create custom space-qualified electronics to power the filament
  - Prototype circuit design completed with ZeCoat IRAD in 2017
- Test the BPD coating process with (31) sources in a simulated space environment using a 1.5-m LN2 cryogenic shroud inserted into a 2.3-m coating chamber

Questions?