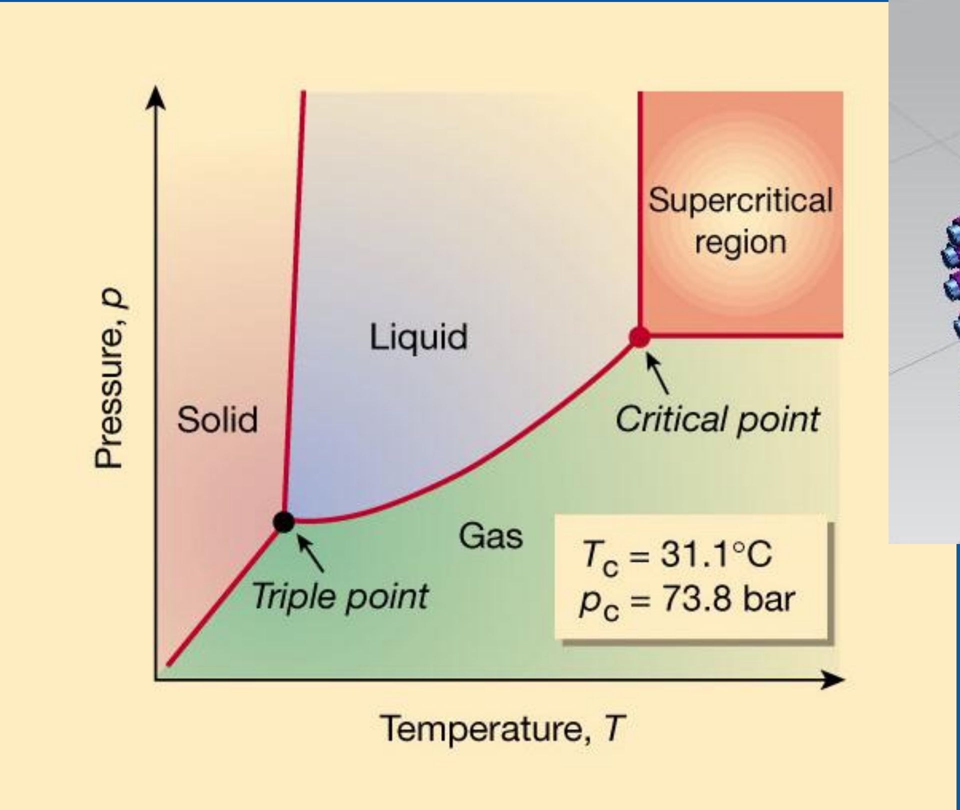
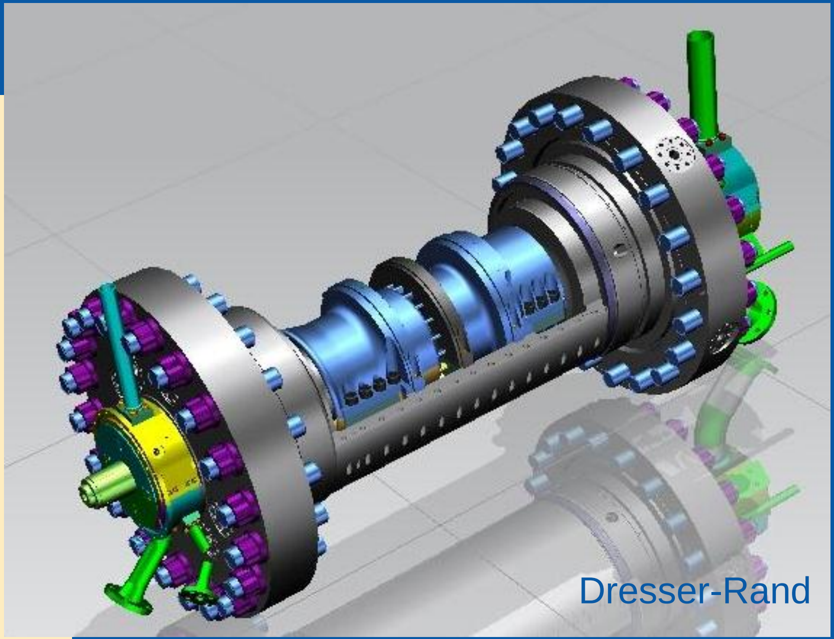
10 MW Supercritical-CO_2 Turbine Project





Dresser-Rand

Craig S. Turchi, PhD

SunShot Program Review
April 23-25, 2013
Phoenix, AZ

Project Summary

Award:	DE-EE-0001589
Title:	10 MW s-CO_2 Turbine Test
Overall Budget:	$16 million ($8M DOE, $8M industry)
Start date:	October 1, 2012

		2013				2014				2015			
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13
Phase 1 – Design													
Phase 2 – Fabrication													
Phase 3 – Operation													

10 MW s-CO_2 Turbine Test

Goal: Design, fabricate, and validate a supercritical-CO_2 (s-CO_2) power cycle of nominally 10 MWe that is capable of operation at up to 700°C under dry cooling conditions.

Innovation: Demonstrate the inherent efficiencies of the s-CO_2 power turbine and associated turbomachinery at a design and scale relevant to commercial power generation.

NREL NATIONAL RENEWABLE ENERGY LABORATORY

ECHOGEN power systems

Sandia National Laboratories

Barber Nichols

THE UNIVERSITY of WISCONSIN MADISON

ABENGOA SOLAR

EPRI ELECTRIC POWER RESEARCH INSTITUTE

10 MW s-CO_2 Turbine Team

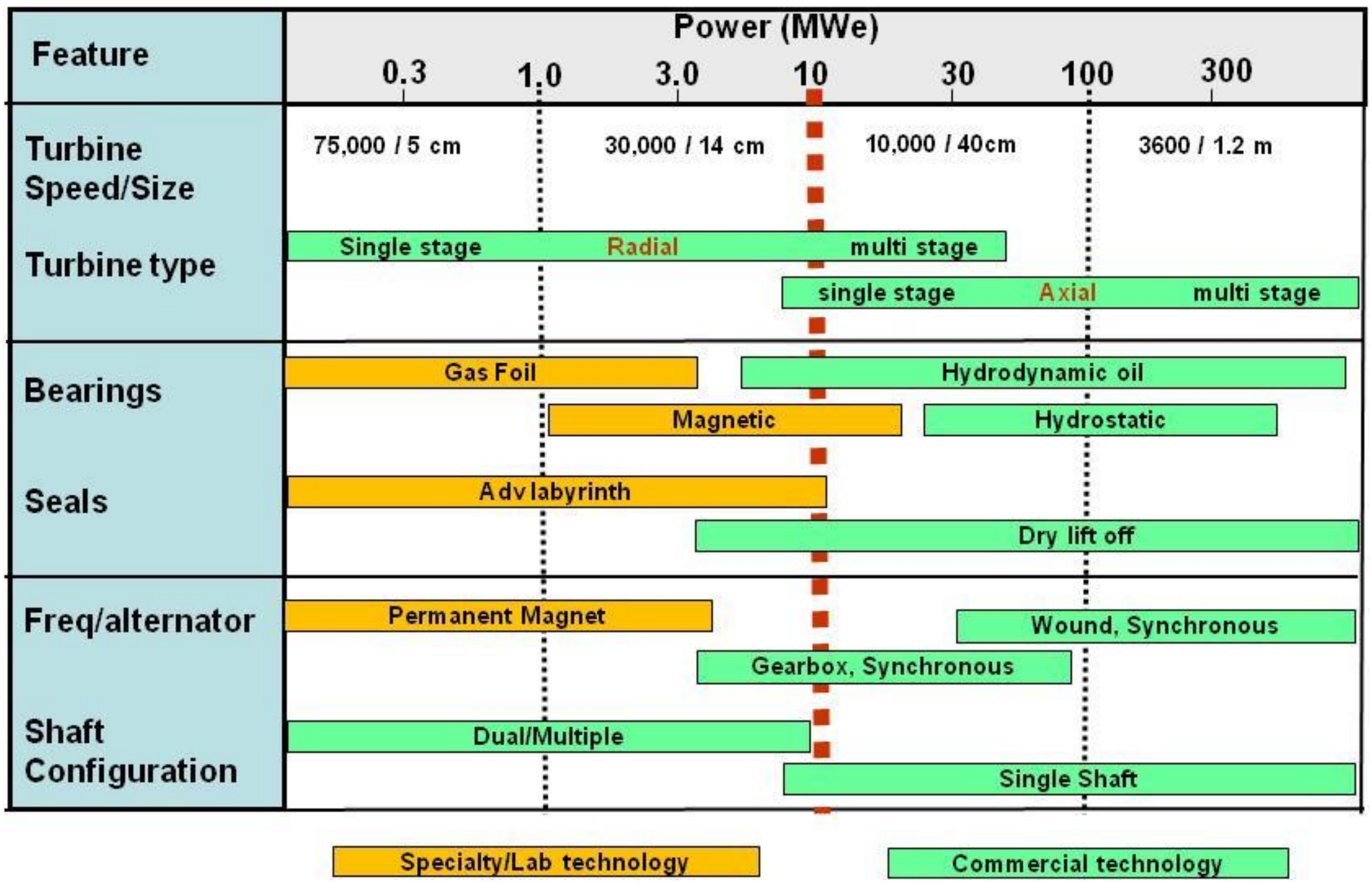
Partner	Roles and Responsibilities
NREL (prime)	Project management s-CO_2 cycle modeling; annual simulations and LCOE estimates Operation staff support
Abengoa Solar	Integration of s-CO_2 into CSP commercial systems Analysis of market for s-CO_2/CSP Heat input system and heat rejection system design and fab Operation staff support
Echogen Power Systems	Turbomachinery and test loop system design Compressor and turbine fabrication; Test loop system fabrication Analysis of market for s-CO_2 power systems Operation utilities and staff support
Sandia	Site preparation, system installation and operation Recompression loop test operations at high CIT
UW-Madison	Materials of construction, corrosion assessment
Barber-Nichols	System design consulting; Component manufacturing as needed
EPRI	Tech. promotion and identification of potential comm. projects Materials selection assistance to UW-Madison

Project Objectives

1. Design and fabricate s-CO_2 power turbine using conventional, scalable system design
2. Construct ~10 MWe recuperated s-CO_2 test loop
3. Run loop at temperatures up to 700°C
4. Test cycle operation at high compressor inlet temps (i.e., dry-cooled conditions)
5. Validate performance models with experimental data
6. Simulate annual operation of system configurations that achieve SunShot goals
7. Advance technology to commercial demonstration

Why 10 MWe Scale?

- 10 MW allows use of commercial design technologies
- Axial turbine design chosen to facilitate scale-up to larger capacity



Project Tasks

Phase 1 - Design

- 1.1 Corrosion and Materials Analysis
- 1.2 Detailed Test Plan Development
- 1.3 Test Loop Design
- 1.4 Modeling and Simulation of Cycles
- 1.5 Commercial Power Cycle
- 1.6 CSP Commercial Deployment Path
- 1.7 Site Preparation

Phase 2 - Fabrication & Installation

- 2.1 Corrosion and Materials Analysis (cont.)
- 2.2 Test Loop Construction
- 2.3 Installation & Checkout
- 2.4 Modeling & Simulation
- 2.5 Conceptual Design Study of Commercial CSP System

Phase 3 - Operation & Simulation

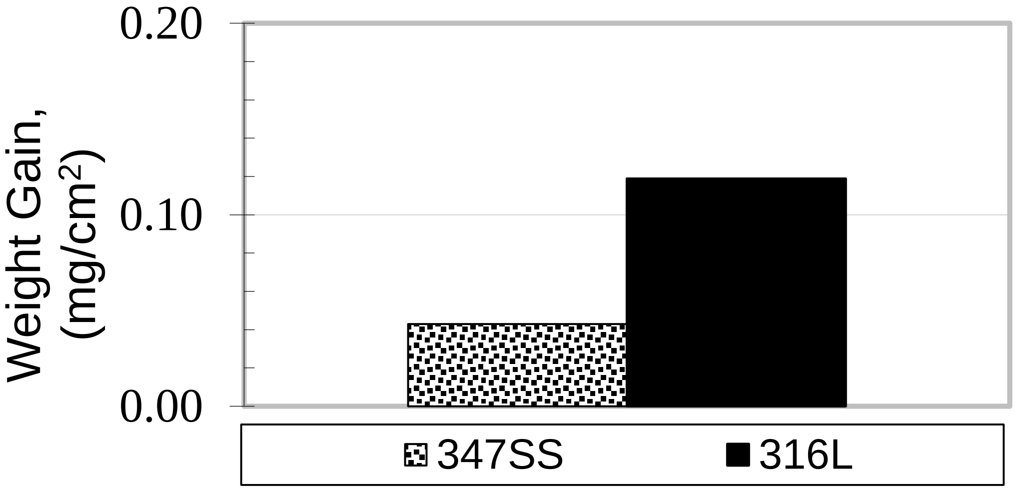
- 3.1 Corrosion and Materials Analysis (cont.)
- 3.2 Low-temp operation (550C)
- 3.3 High-temp operation (>650C)
- 3.4 System Model Validation
- 3.5 Response and Control of Recompression Cycle

Project Management & Reporting

Alloy Corrosion Tests (UW-Madison)

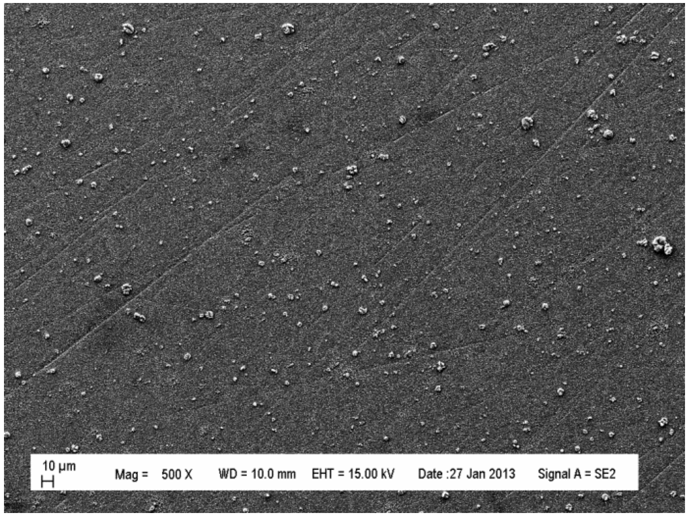
Alloy	C	Fe	Cr	Ni	Mn	**Nb**	**Mo**	Si	Cu	Co
316L	0.045	64.3	17.4	13.3	1.7	**-**	**2.7**	0.43	-	-
347ss	0.051	68.5	17.7	9.62	1.66	**0.72**	**0.38**	0.77	0.38	0.20

200 hours exposure to CO_2 at 650C and 200 bar:

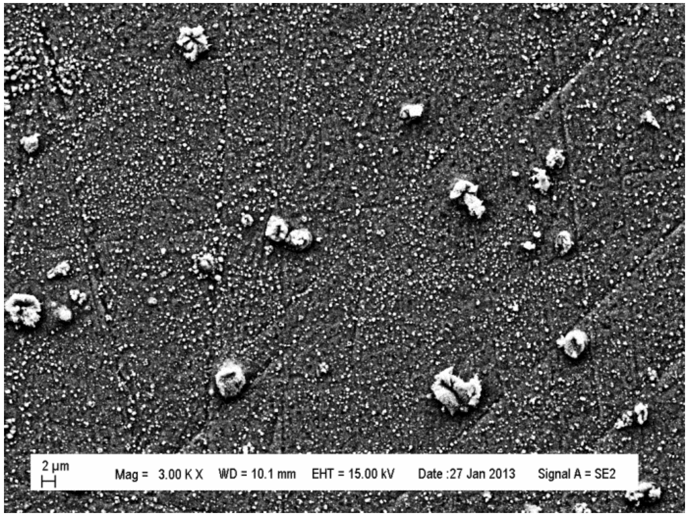


347 SS Surface SEM

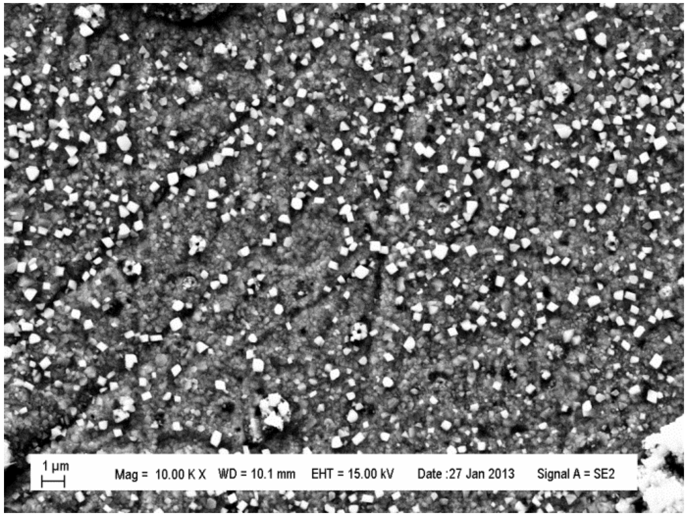
No Large Oxidation Cluster



Oxide particles

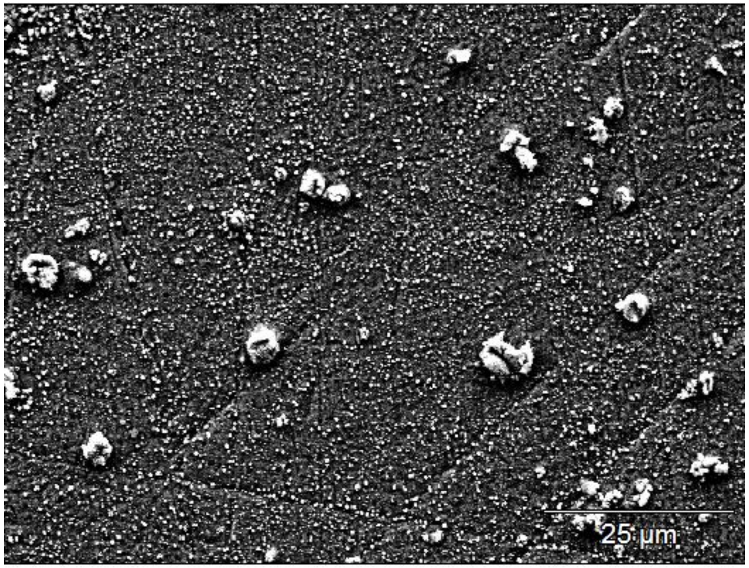


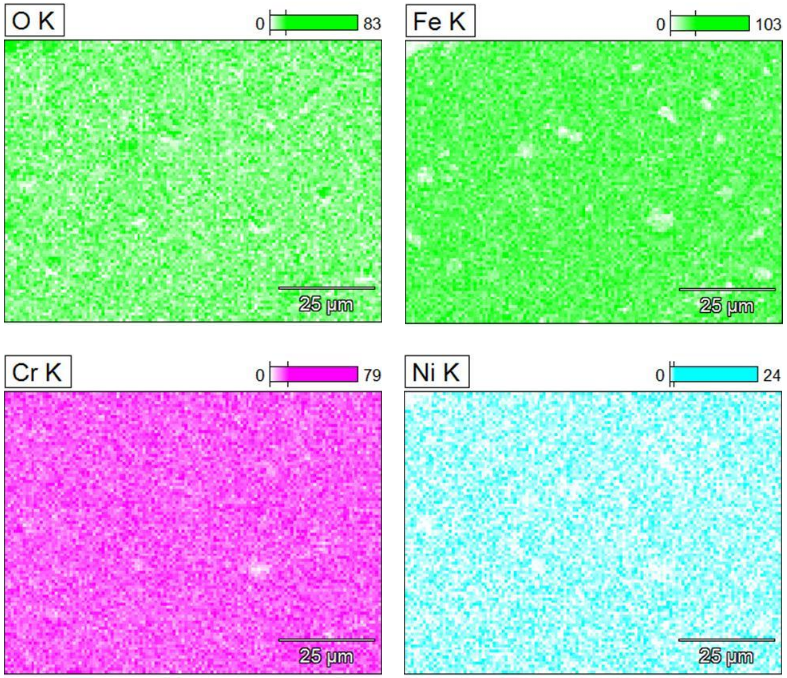
Smaller grainy oxide

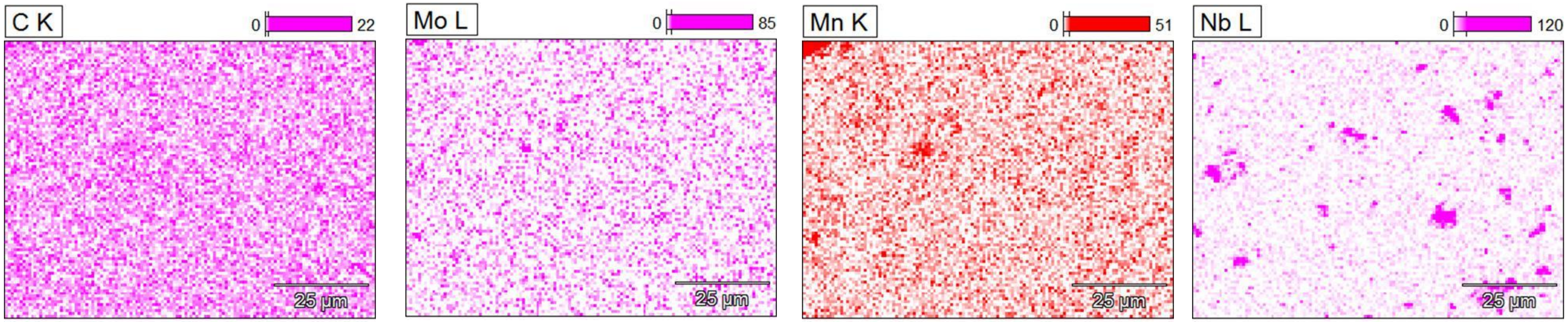


347 SS Elemental Analysis via EDS

Nb oxide particles







Initial Results: 347 and 316L

1. 316L shows higher weight gain than 347ss despite their similar composition.
2. The major oxide is large Fe oxide clusters in 316L and Nb oxide particles in 347ss. Small grainy Mn-rich oxides found in both alloys, but their number density is higher in 347ss than in 316L.
3. The reason for formation of different oxides in these two similar alloys is still being investigated.
4. Other alloys under analysis: Inconel 800H, Haynes 230, AFA-O6C

Test Bed for High-Temp Turbine

The SunShot test hardware consists of:
Echogen EPS100 System with high-temp turbine, high-temp recuperator, and modified compressor + 700C heat source + dry cooling system

Echogen's first-of-kind EPS100 process skid being transported for testing.

Test Site

Testing will occur at Sandia National Laboratories’ Nuclear Energy Systems Lab (NESL), host site for Brayton cycle research.

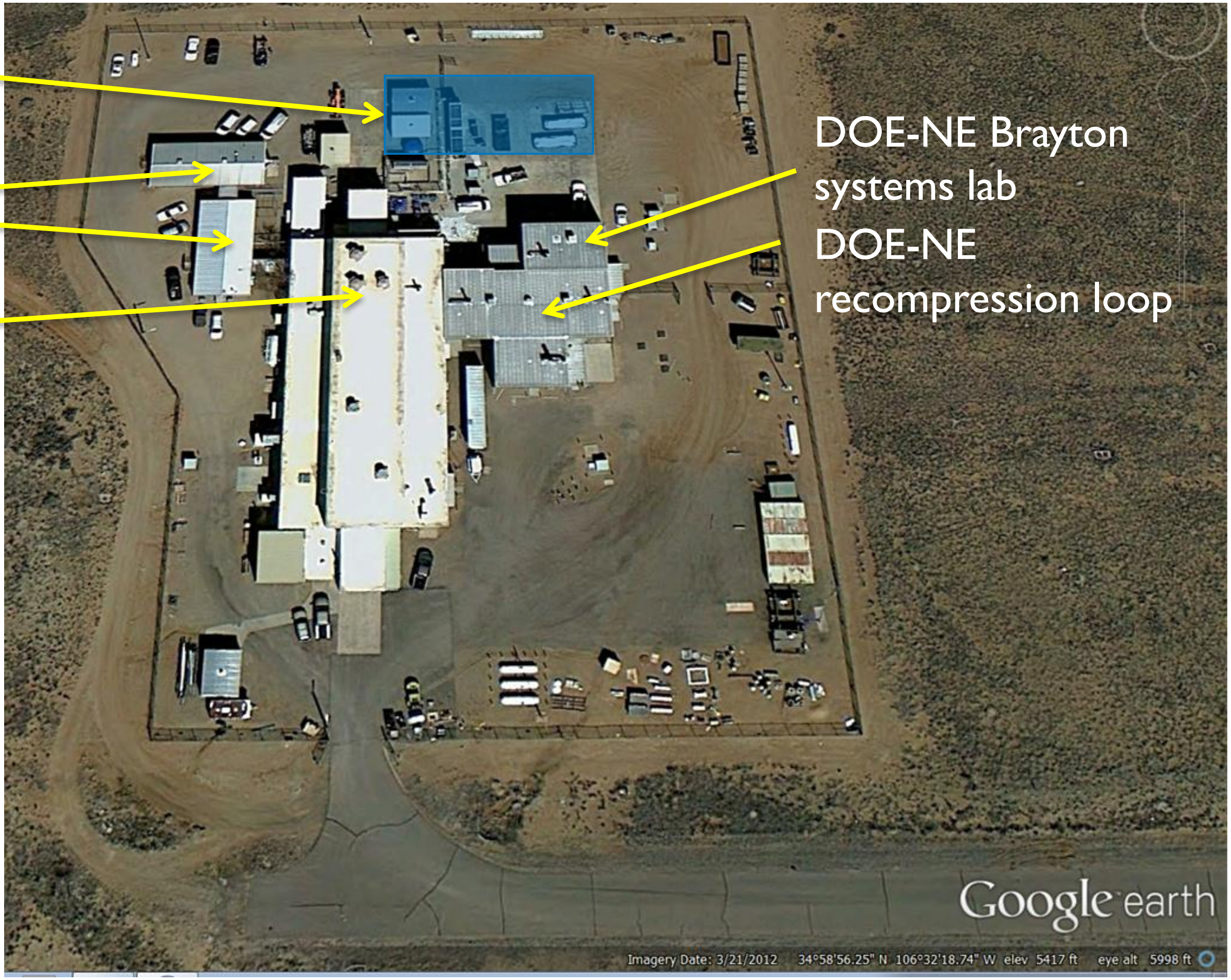
Site Preparation

Nuclear Energy Systems Lab (NESL)

Air-cooled HX location
~6000 sq. ft

Offices

Highbay for
10 MW turbine
skids



SunShot Path for s-CO_2 Brayton Cycle

Contributions under the 10 MW s-CO_2 Turbine project are highlighted in orange.