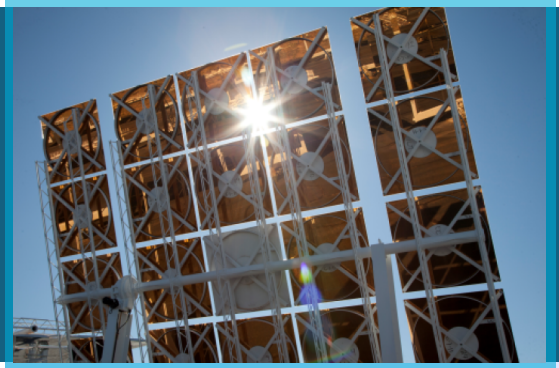
This paper describes objective technical results and analysis. Any subjective views or opinions that might be expressed in the paper do not necessarily represent the views of the U.S. Department of Energy or the United States Government.

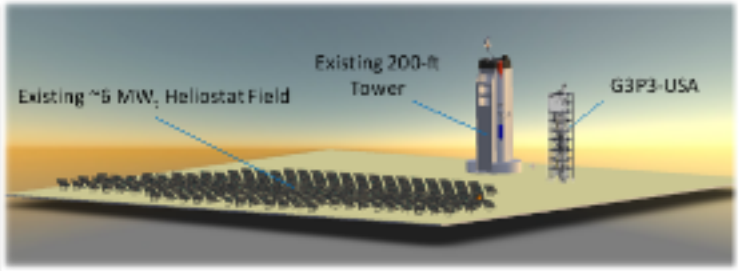
SAND2021-10249C

DOE Gen3 CSP Topic 1 Phase 3 Continuation Presentation
February 17, 2021

Sandia National Laboratories

G3P3 – Project and Test Planning





PRESENTED BY

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Contributors:

Georgia Institute of Technology, King Saud University, DLR, CSIRO, U.Adelaide, ANU, CNRS-PROMES, EPRI, Bridgers & Paxton/Bohannan Huston, SolarDynamics, Solex Thermal Science, Vacuum Process Engineering, Allied Mineral Products, Matrix PDM, CARBO Ceramics, Saudi Electricity Company

SNL Programmatic Review 1269033

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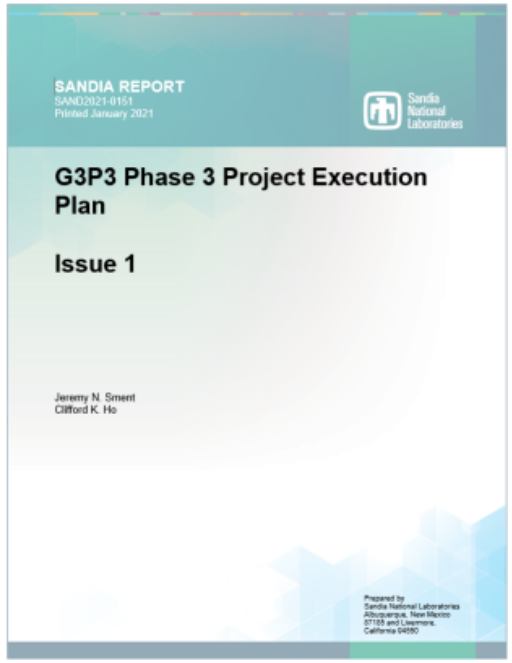
PROPRIETARY – DO NOT DISSEMINATE

Phase 3 PEP – Work Breakdown Structure



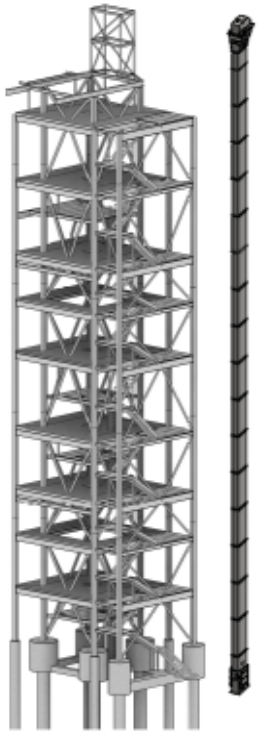
- **Programmatic 1**
  - ES&H 1.3
  - Contracting 1.4
  - Permitting 1.5
- **Procurement and Fabrication 2**
  - Receiver 2.2
  - Storage 2.3
  - Heat Exchanger 2.4
  - sCO_2 Loop 2.5
  - Particle Lift 2.6
- **Construction and Assembly 3**
  - Civil 3.3
  - Structural 3.4
  - Electrical 3.5
  - Component Installation 3.7
- **Component/System Commissioning 4**
  - Charge System (gradual fill) 4.1.1
  - Particle Loop (all pathways) 4.1.4
  - Storage (electric heat) 4.3.3
  - Receiver (on sun) 4.4
  - Heat Exchanger 4.5
  - sCO2 Loop 4.6
- **Component Testing 5**
  - Receiver 5.2
  - Storage 5.3
  - Heat Exchanger 5.4
  - sCO2 Loop 5.5
  - Particle Lift 5.6
  - Particle 5.7
- **System Testing 6**
  - Startup Operations 6.1
  - Continuous Operations 6.2
  - Storage Operations 6.3
  - Shutdown Operations 6.4

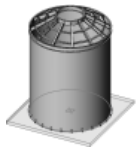
Most component/system test objectives can be achieved simultaneously

Project Execution Plan:

Procurements and In-House Fabrication

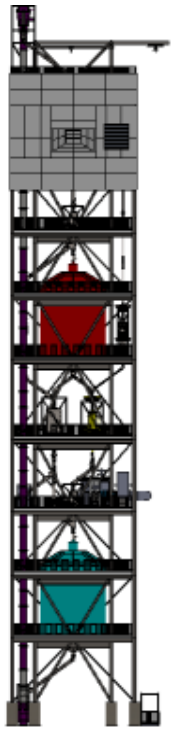
Tower Construction (by Summit)



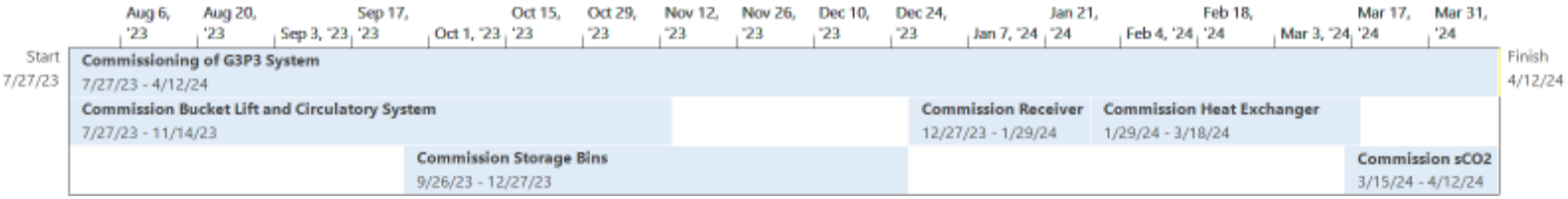


Storage Shells and Lift Installation during tower erection

Install Components in Tower



Commissioning



Storage and Particle Circulatory System:

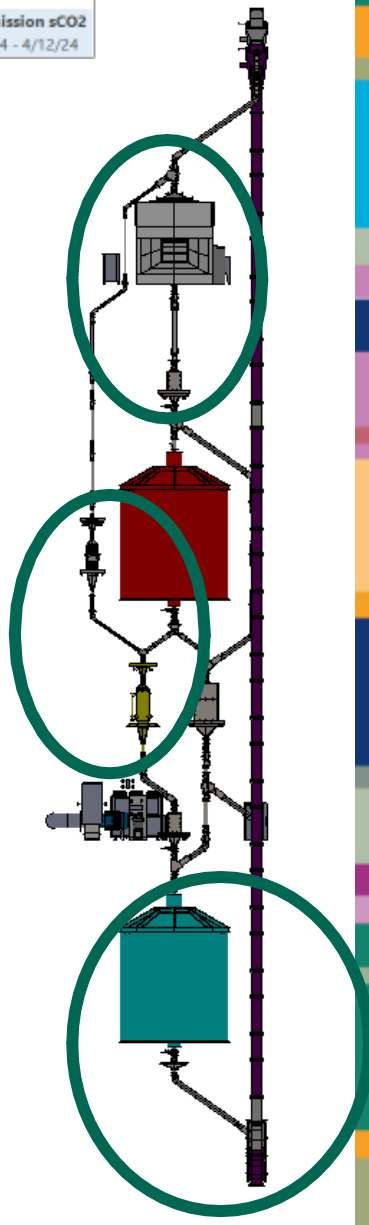
1. All controls operational
2. Gradual charging with particles
3. Increase temperature with auxiliary heater

Heat Exchanger:

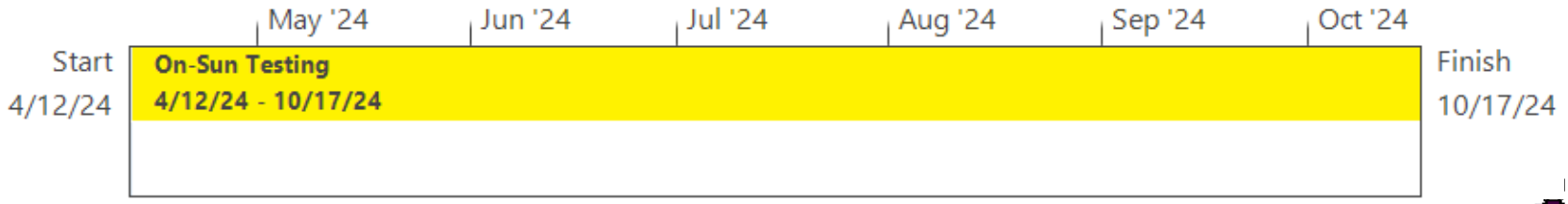
1. Hydrotesting
2. Measure leak rate while pressurized for >12hrs
3. Gradually bring to operating temperature

Receiver:

1. Gradually bring to temperature on-sun with no observable damage while increasing flux/flowrate
2. Demonstrate operation of slidegate response to maintain particle curtain stability and particle temperature within bounds

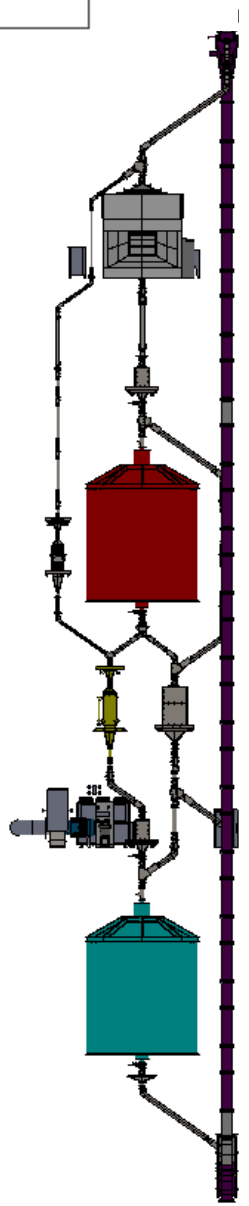


On-Sun Testir



- System Milestones:
  1. Total energy delivered to sCO2
  2. System performance and model validation

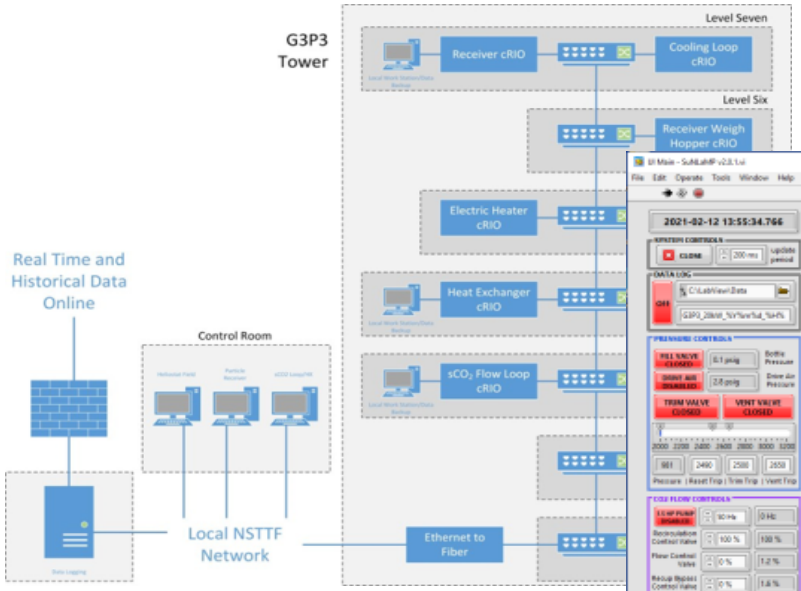
- Operational Modes:
  1. System start-up and shutdown
  2. Emergency operations
  3. Design-point operations
  4. Load follow/weather transients



On-Sun Testing: Data Acquisition & Management

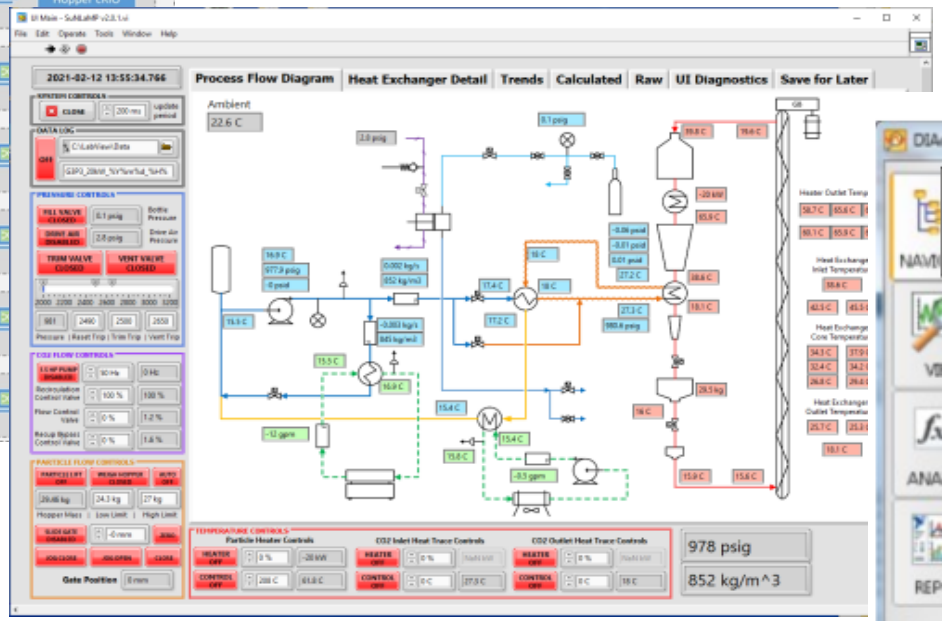
Three-part data management plan

Architecture



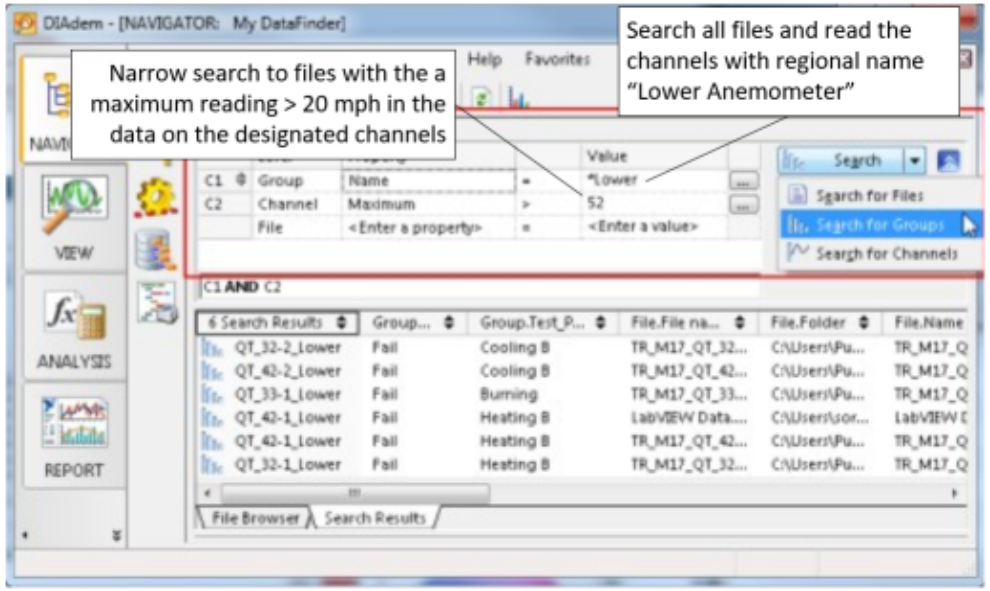
National Instruments Hardware I/O

Data Acquisition



24/7 data acquisition & controls

Archive and Retrieval

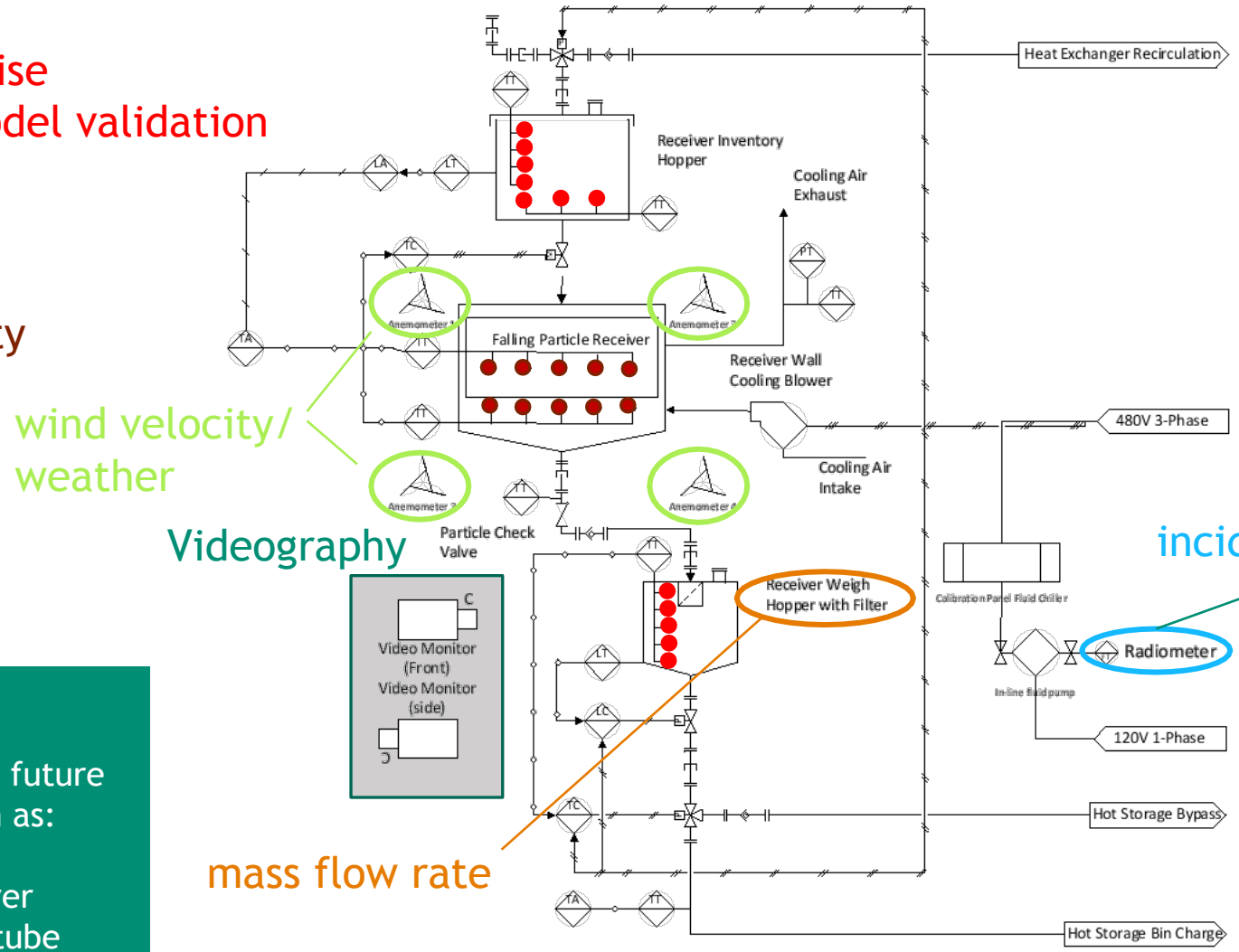


Citadel database/Diadem interface

On-Stun Test Plan: Receiver

Test Metrics:

- Particle temperature rise
- Advective heat loss model validation
- Thermal efficiency
- Receiver back-wall temperatures
- Particle curtain stability
- Particle loss



wind velocity/ weather

Videography

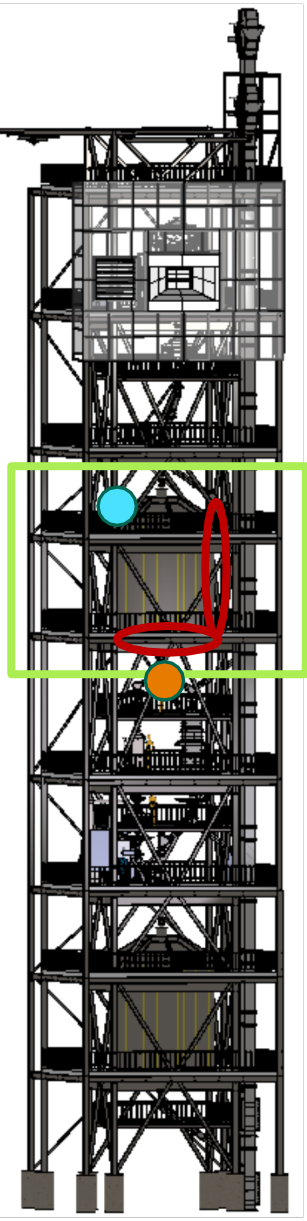
incident power

mass flow rate

Modified tower to accommodate future work on alternative designs such as:

- KSU Obstructed Flow
- DLR *CentRec* Rotating Receiver
- CNRS – Fluidized particle-in-tube

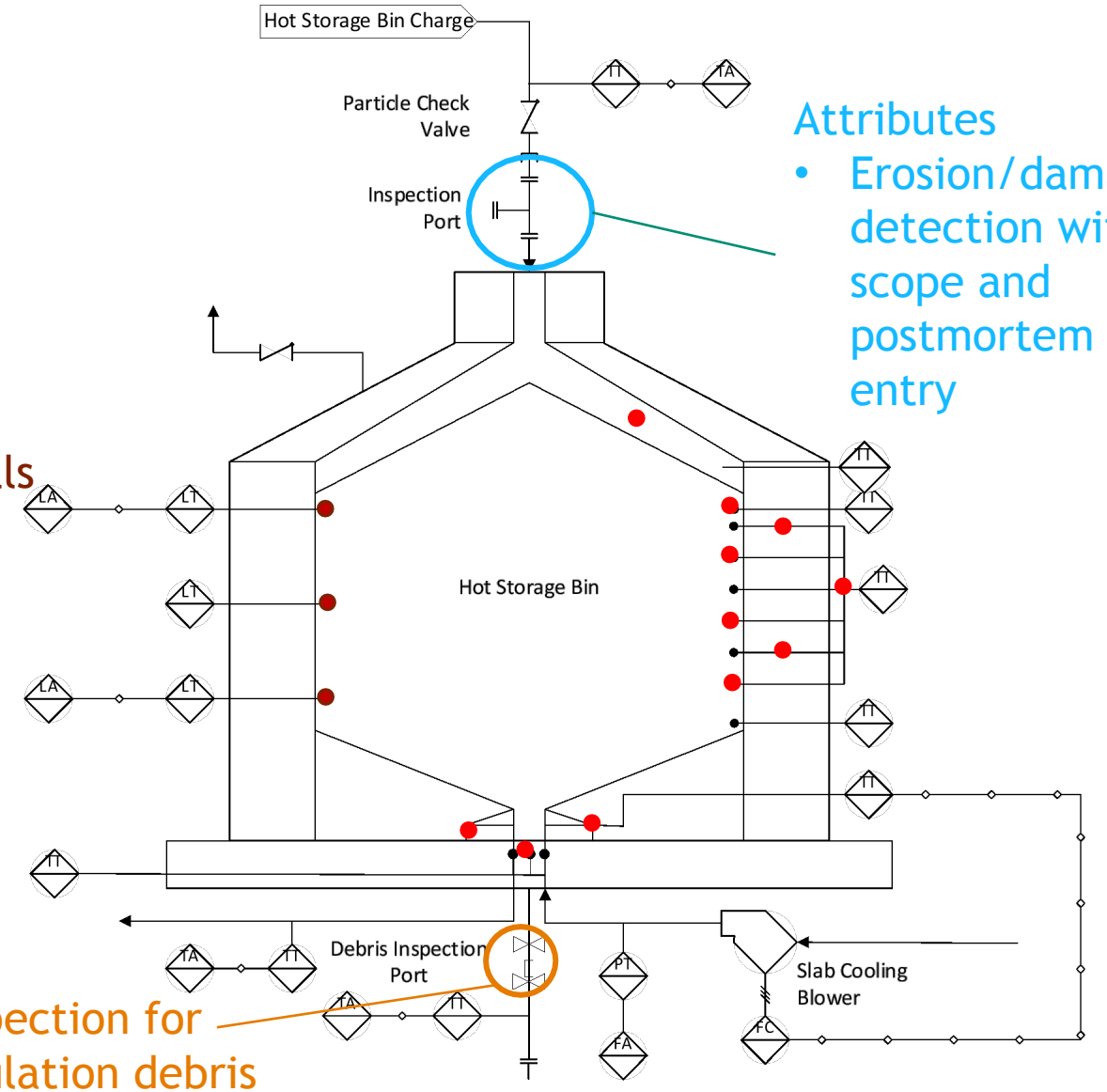
Phase 3 Risk Reduction and Test Plan: Storage



Test Metrics

- Particle outlet temperatures
- Heat loss through walls
- Heat loss to air
- Time to Equilibrium
- Stress calculations
- Condition of Foundation/Walls

Alternative Designs (G3P3-KSA):
- Thermal-expansion layer
- Pre-cast panels

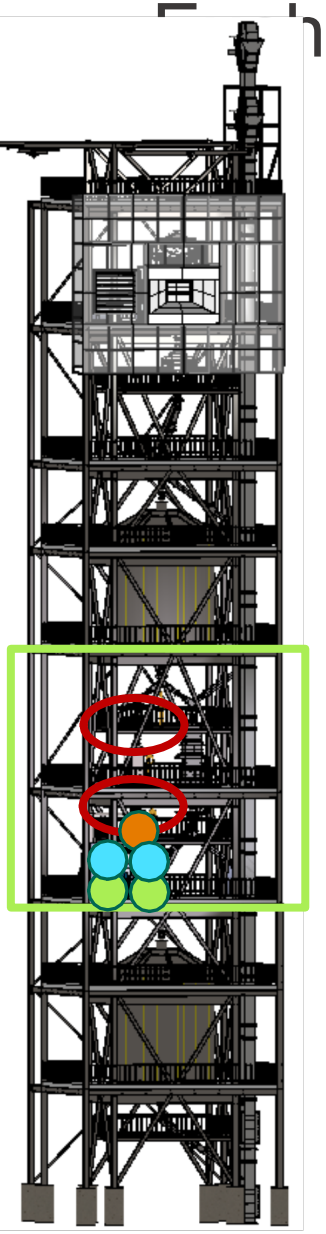


Attributes

- Erosion/damage detection with bore scope and postmortem human entry

Inspection for insulation debris

Phase 3 Risk Reduction and Test Plan: Particle-sCO2 Heat Exchanger

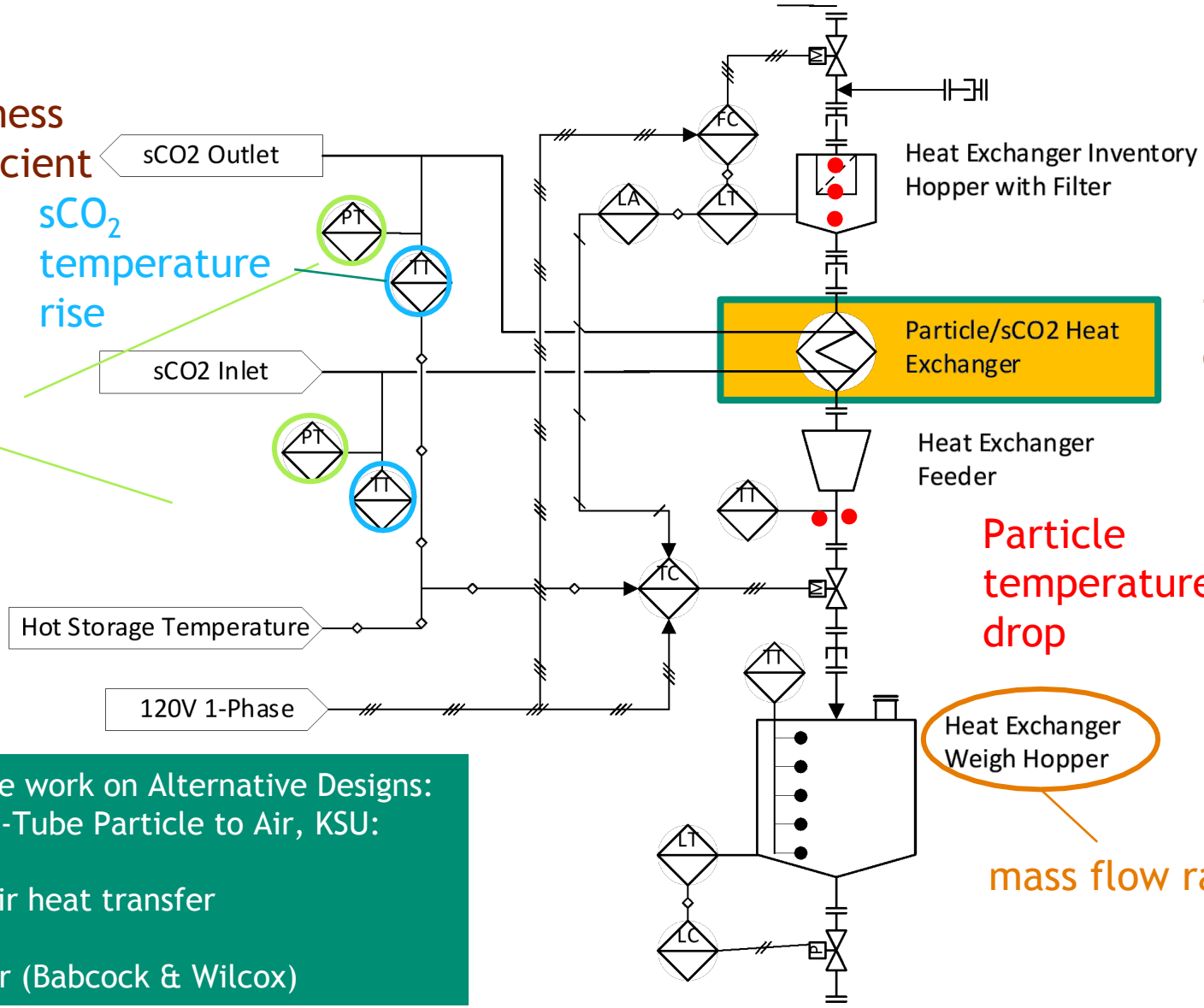


Test Metrics:

- Particle-sCO_2 heat exchange effectiveness
- Heat transfer coefficient
- Pressure drop
- Control Studies
- Model Validation

sCO_2 temperature rise

sCO_2 pressure drop



Postmortem inspection of diffusion bonded plates

Particle temperature drop

mass flow rate

Adaptable Platform for future work on Alternative Designs: Moving Packed Bed Shell-and-Tube Particle to Air, KSU:

- ΔT=416° C and 4 bar
- Particle-to-compressed air heat transfer

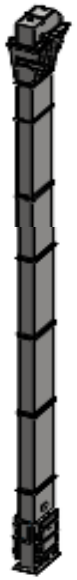
Fluidized-bed heat exchanger (Babcock & Wilcox)

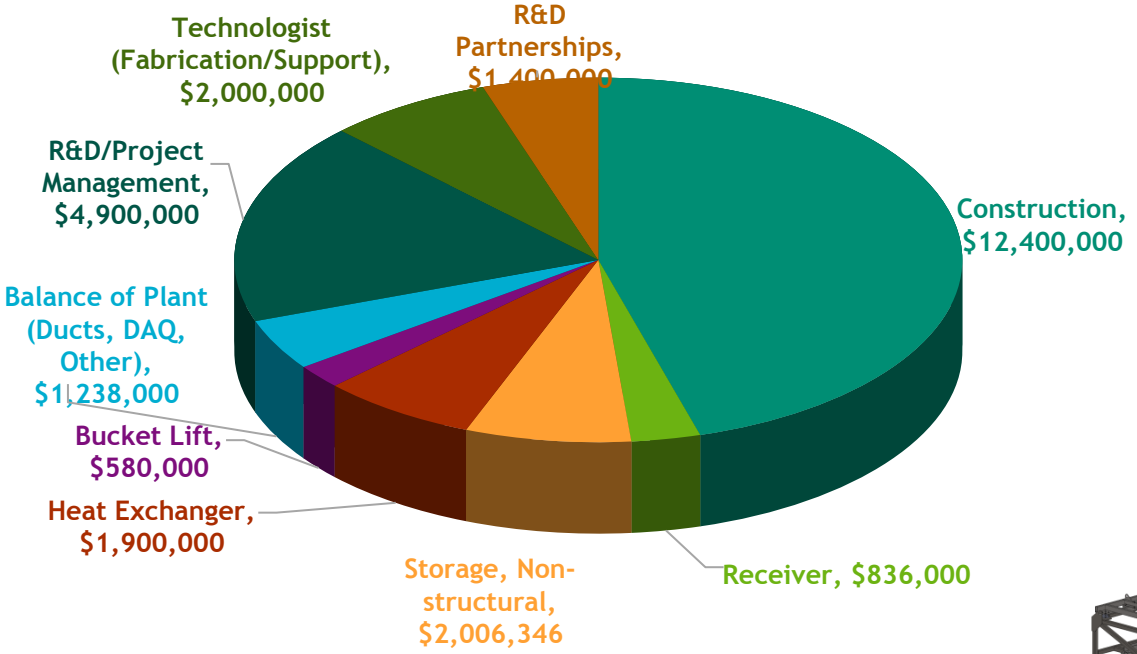
Procurement Process

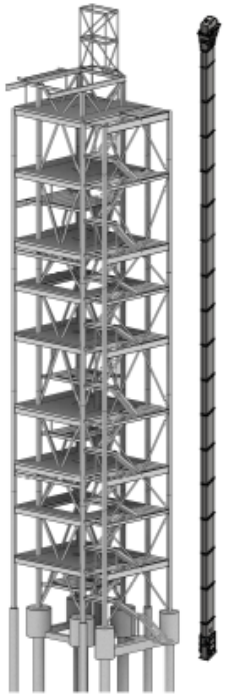
- 10 Subsystems divided into 86 pieces of equipment
- Over 355 part assemblies
- Over 5000 procurements expected including instrumentation

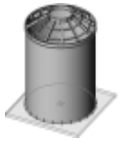
Subsystem	Major Particle Equipment List	Parts/Assemblies	Drawing Number	Description	Model Number	Material	Source of Estimate	Estimate Category	Qty	Min Cost	Nominal Cost	Max Cost	Uncertainty Bounds	Make/Buy	Lead Time (wks.)
900000 Cold Storage Bin $274,788.82	905000 Floor	Slab Cooling Plate	905932	actively cooled thermal gap under outlet	N/A	N/A	McMaster	Online Search	0	$0	$0	$0	±5%	Buy	
		Slab Cooling Plate Blower	905933	actively cooled thermal gap under outlet	N/A	N/A	McMaster	Online Search	0	$0	$0	$0	±5%	Buy	8
		Outlet riser	905934	Medium Density Refractory Collar for outlet	Riser^Storage Bir	Pumplite	Allied Mineral	Quoted	1	$16,021	$16,021	$16,021	-0%/+5%	Buy	8
		Outlet plate	905935	Steel outlet plate	Outlet Pipe Rev B	SS316	Winchester Precision T	Quoted	1	$11,009	$11,009	$11,009	-0%/+5%	Buy	14
		Outlet Pipe Wrap	905936	Microporous Insulation	Elmtherm 1000 M	Microporc	Elmlin	Quoted	4.5	$186	$186	$186	-0%/+5%	Contrac	3
		Wool Outlet Insulation	905937	Fiber wool wrapping 2" thick 24" wide	SP-700K-1/4" 24 ir	Ceramic F	Morgan Thermal Ceran	Quoted	25	$201	$201	$201	-0%/+5%	Make	4
	906000 Walls	HD Liner Pre-cast Panels	906938	($10472)	XD19296-01	Tuffcrete	Allied Mineral	Costed Elsewh	40	$0	$0	$0	0	Buy	6
		Wall Liner Gaskets	906939	refractory layers	High-Temperatur	TBD	Allied Mineral	Parametric Esti	40	$4,122	$5,152	$6,182	±20%	Buy	4
		Microporous Interstitial Wall Ir	906940	Microporous insulation board 500x610x6mm	Elmtherm 1000 M	Microporc	Elmlin	Quoted	5	$230	$230	$230	-0%/+5%	Buy	8
		HD Liner Gunite Tuffcrete	906941	Shotcrete application of Tuffcrete material	High-Density Ref	Tuffcrete	Allied Mineral	Quoted	48000	$27,048	$27,048	$27,048	-0%/+5%	Buy	4
		HD Liner Gunite Tuffcrete Binde	906942	High Calcium Hydreated Lime	High-Density Ref	SSHotlime	Allied Mineral	Quoted	350	$205	$205	$205	-0%/+5%	Buy	4
		LD Refractory Insulation	906943	Calcium Silicate Board 36x24x4	SS1100 E 100 mm	Calcium S	Skamol	Quoted	305	$16,100	$16,100	$16,100	-0%/+5%	Buy	8
		Microporous Insulation Panels	906944	Microporous insulation board 500x610x50mm	Elmtherm 1000 M	Microporc	Elmlin	Quoted	300	$29,900	$29,900	$29,900	-0%/+5%	Buy	10
	907000 Ceiling	Ceramic Fiber Modules	907945	(expandable)	MaxBlok LTS	Ceramic F	Nutec	Quoted	43	$8,407	$8,407	$8,407	-0%/+5%	Buy	6
		Ceramic Fiber Modules	907946	12 x 12 x 12 modules	MaxBlok LTS	Ceramic F	Nutec	Quoted	10	$449	$449	$449	-0%/+5%	Buy	6
		Bin Cover Receiver	907947	Ring around the inlet plug	XD19296-P03	Pumplite	Allied Mineral	Quoted	12	$5,368	$5,368	$5,368	-0%/+5%	Buy	10
		Inlet Hatch Retaining Ring	907948	Steel surrounding cover receiver	Retaining Ring<1	SS316	Winchester Precision T	Quoted	1	$32,976	$32,976	$32,976	-0%/+5%	Buy	25
		Removeable Plug Cover Shell	907949	Removeable Support For Inlet Plug	Cover Shell<1>	SS316	Winchester Precision T	Quoted	1	$23,324	$23,324	$23,324	-0%/+5%	Buy	8
		Inlet Hatch Removeable Plug	907950	Pumplite 40 molded refractory inlet	Q20165	Pumplite	Allied Mineral	Quoted	1	$2,762	$2,762	$2,762	-0%/+5%	Buy	8
		Microporous Roof Insulation	907951	Microporous insulation board 500x610x12mm	Elmtherm 1000 M	Microporc	Elmlin	Quoted	100	$6,900	$6,900	$6,900	-0%/+5%	Buy	10
	908000 Shell	Storage Shell Wall	908952	Full Penetration Welded Plates	Shell	A572 GRA	Matrix PDM	Costed Elsewh	1	$0	$0	$0	0	Buy	
		Storage I-beams/Rings	908953	W10 I-Beams, C12 channel rolled, C8 Deck Supports	Roof Structure	A992 GRA	Matrix PDM	Costed Elsewh	1	$0	$0	$0	0	Buy	
		Storage Roof	908954	1/4" Thick Thin Checkered Diamond Plate	Roof Structure	A992 GRA	Matrix PDM	Costed Elsewh	1	$0	$0	$0	0	Buy	
		Storage Ceiling	908955	1/4" Thick Thin Checkered Diamond Plate	Ceiling Microporc	A992 GRA	Matrix PDM	Budgetary	1	$38,123	$44,850	$51,578	-15%/+15%	Buy	
300000 Particle Valves $210,784.16	301000 Heat Exchanger	Heat Exchanger Slide Gate	301000	6 inch, granular flow control valve	Quote: JBML-4686	Stainless	Pro-Fab	Parametric Esti	1	$23,000	$28,750	$34,500	±20%	Buy	8
	302000 Cold Storage	Cold Storage Bin Isolation Valve	302000	8 inch, granular isolation	custom	Stainless	Pro-Fab	Quoted	1	$17,008	$17,008	$17,008	-0%/+5%	Buy	8
	303000 Heat Exchanger	Post Weigh Hopper Isolation Va	303000	6 inch, granular flow control valve	custom	Stainless	Pro-Fab	Parametric Esti	1	$13,607	$17,008	$20,410	±20%	Buy	8
	304000 Hot Storage Charge	Hot Storage Bin Diverter Valve	304000	8 inch, packed-flow diverter	custom	Stainless	Pro-Fab	Parametric Esti	1	$7,360	$9,200	$11,040	±20%	Buy	8

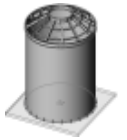
G3P3 Cost Breakdown

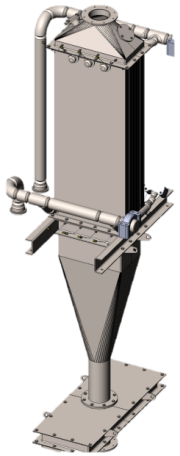


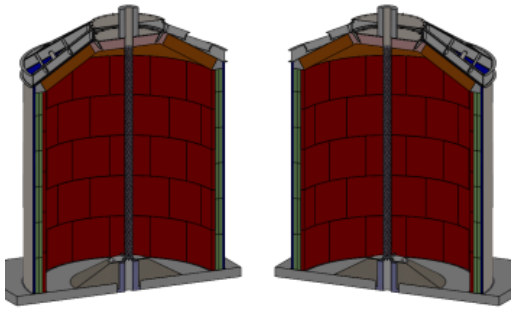


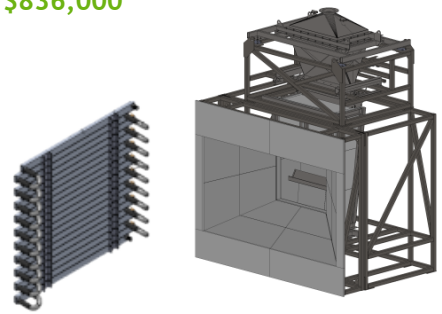


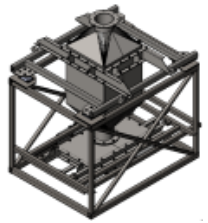












Acknowledgments

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  - DOE Project Managers: Matthew Bauer, Andru Prescod

Thank you