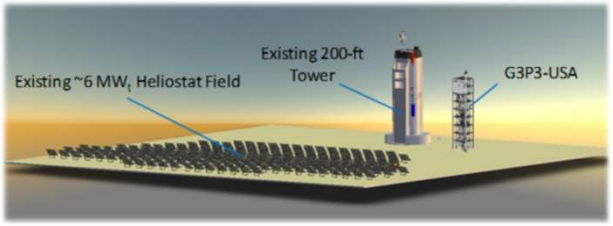
DOE Gen3 CSP Summit 2021

Sandia National Laboratories

G3P3 – Project and Test Planning



PRESENTED BY

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SNL Formal Review 1355248

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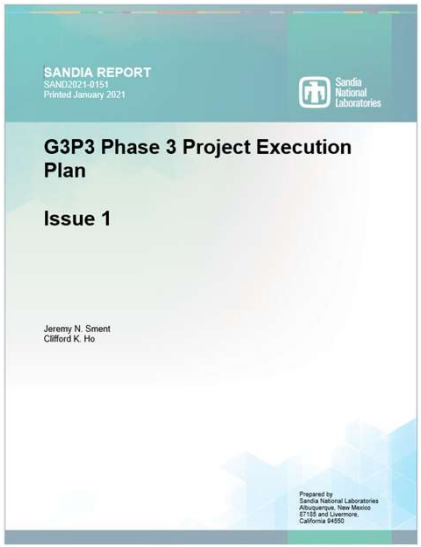
Phase 3 Project Execution Plan – WBS



- **Programmatic 1**
  - ES&H 1.3
  - Contracting 1.4
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- **Procurement and Fabrication 2**
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  - Storage 2.3
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  - Particle Lift 2.6
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  - Storage Operations 6.3
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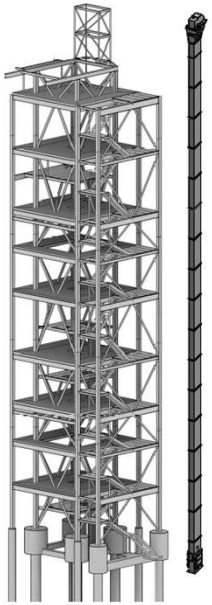
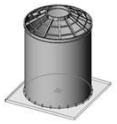
Most component/system test objectives can be achieved simultaneously

Project Execution Plan:

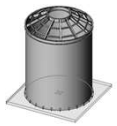
Procurements and In-House Fabrication

Tower Construction (by Summit)

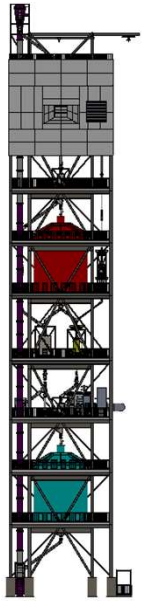




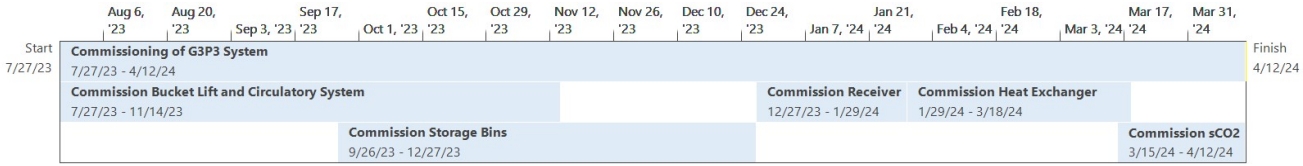
Storage Shells and Lift Installation during tower erection



Install Components in Tower



Commissioning:



Storage and Particle Circulatory System:

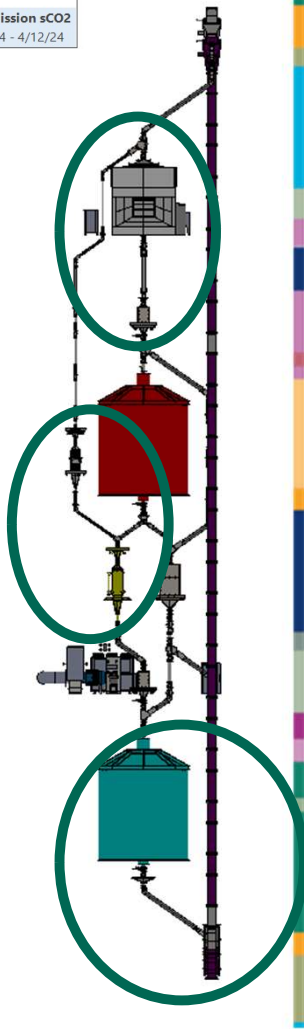
1. All controls operational
2. Gradual charging with particles
3. Increase temperature with auxiliary heater

Heat Exchanger:

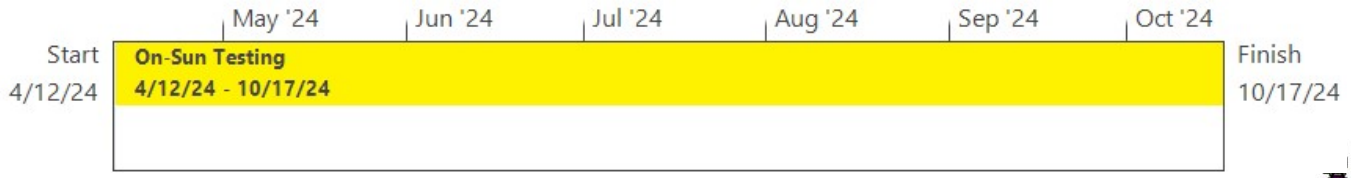
1. Hydrotesting
2. Measure leak rate while pressurized for >12hrs
3. Gradually bring to operating temperature

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

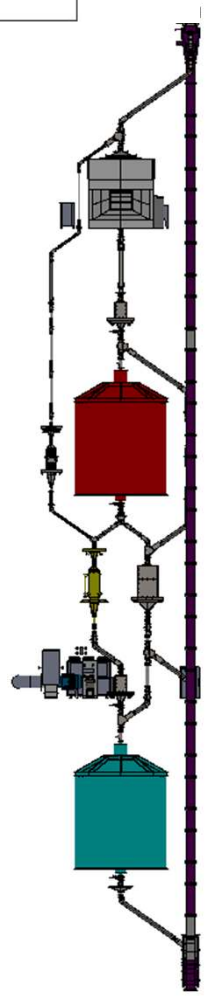


On-Sun Testing:



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

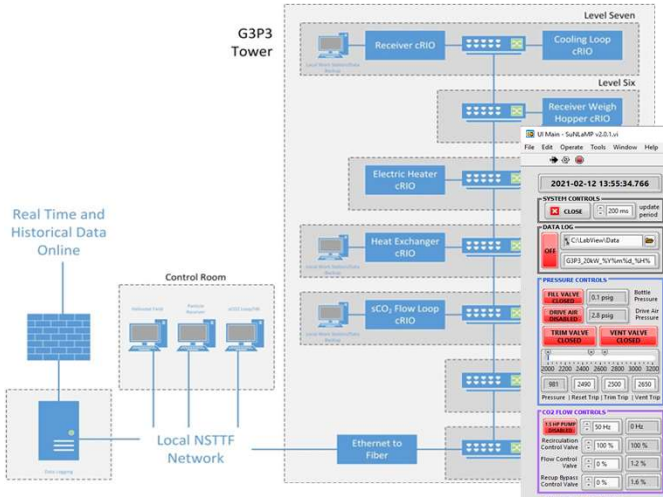
- Operational Modes:
  1. System start-up and shutdown
  2. Emergency operations
  3. Design-point operations
  4. Load follow/weather transients



On-Sun Testing: Data Acquisition & Management

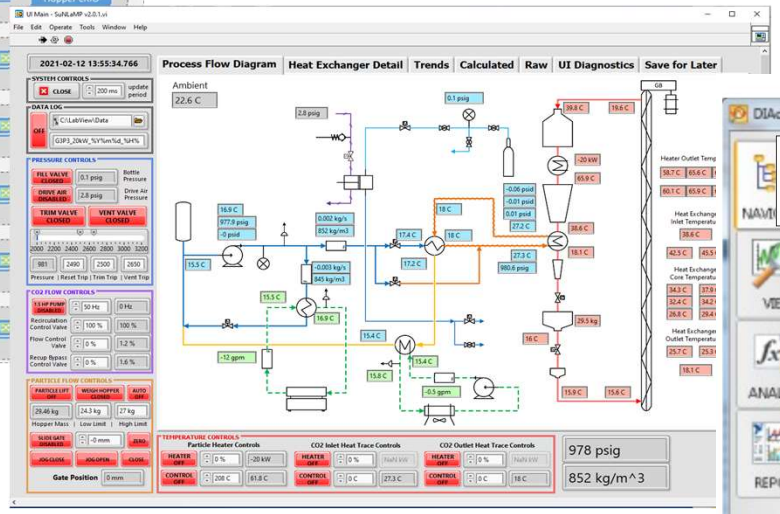
Three-part data management plan

Architecture



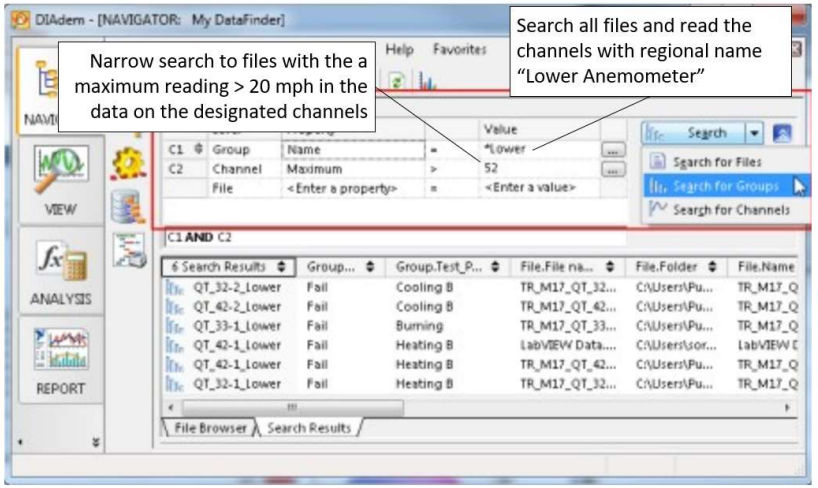
National Instruments Hardware I/O

Data Acquisition



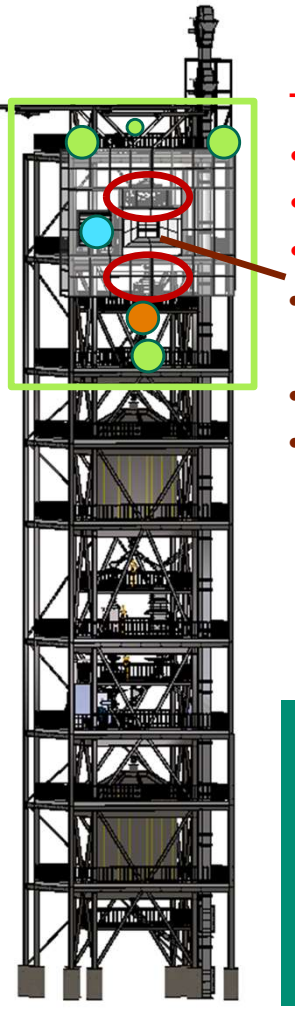
24/7 data acquisition & controls

Archive and Retrieval



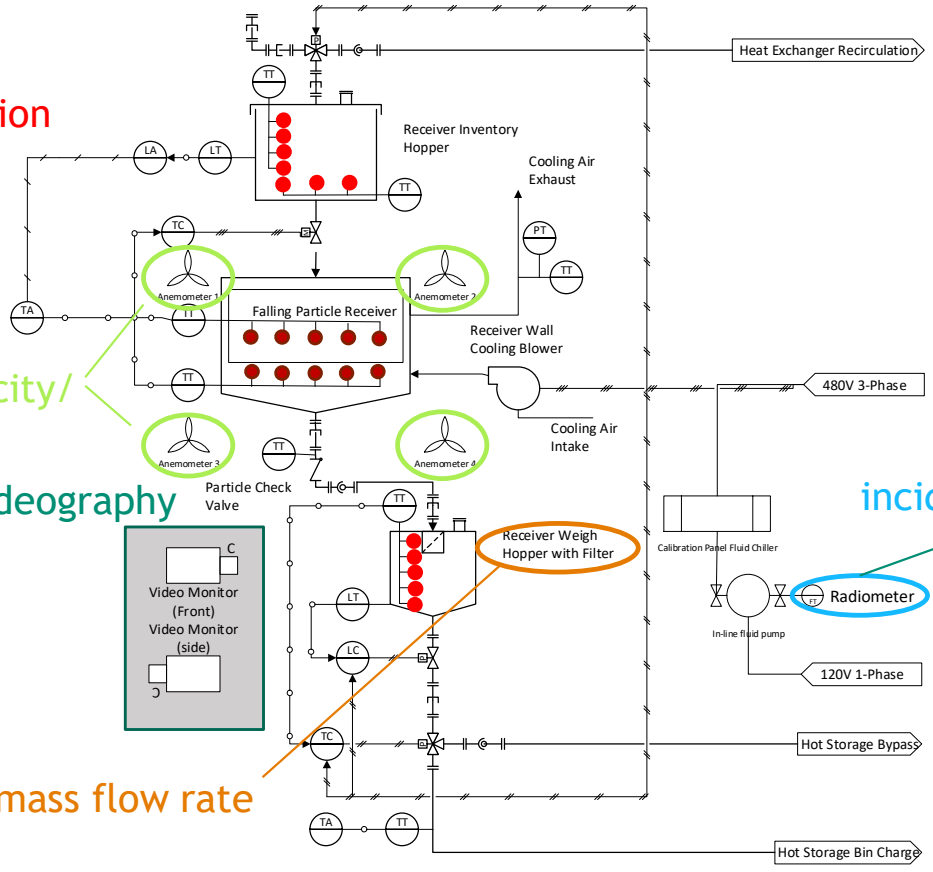
Citadel database/Diadem interface

On-Sun Test Plan: Receiver



Test Metrics:

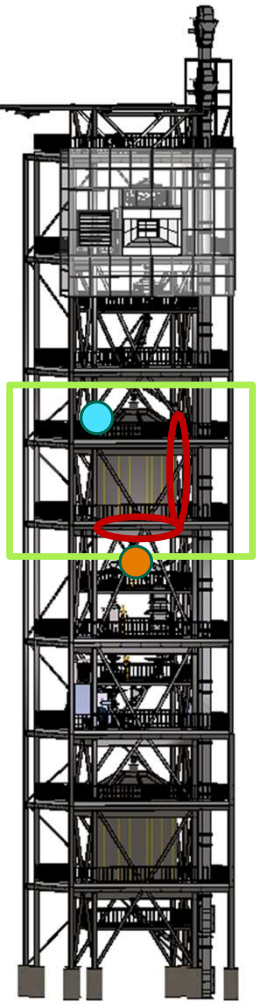
- Particle temperature rise
- Advective heat loss model validation
- Thermal efficiency
- Receiver back-wall temperatures
- Particle curtain stability
- Particle loss



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

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

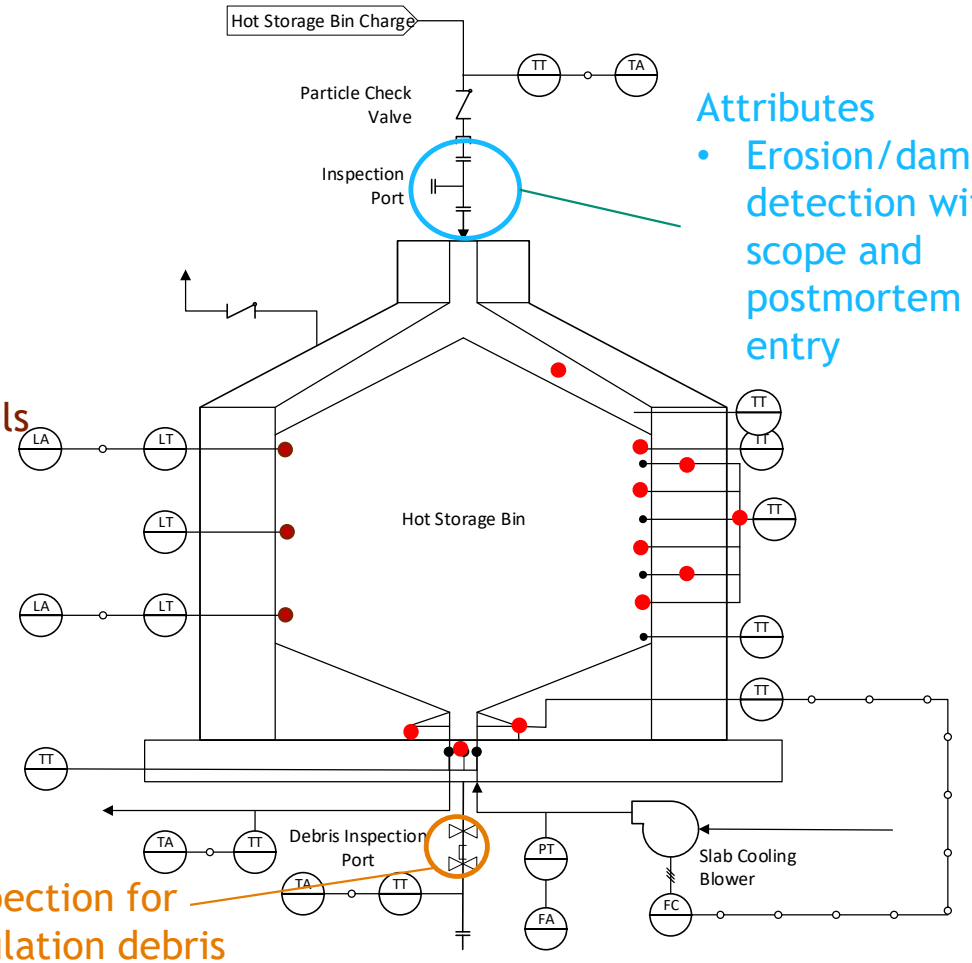
On-Sun Test Plan: Storage



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

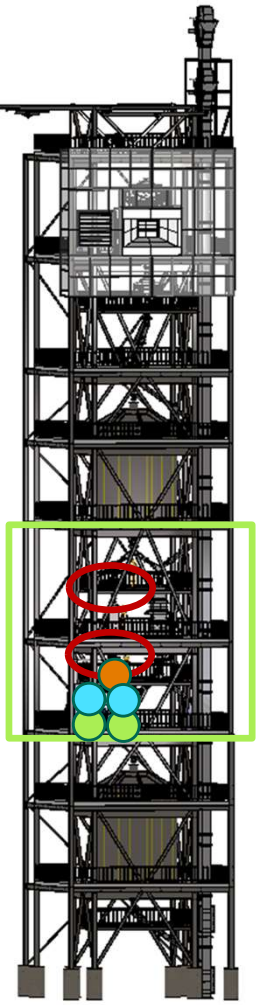


Attributes

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

Inspection for insulation debris

On-Sun Test Plan: Particle-sCO2 Heat Exchanger

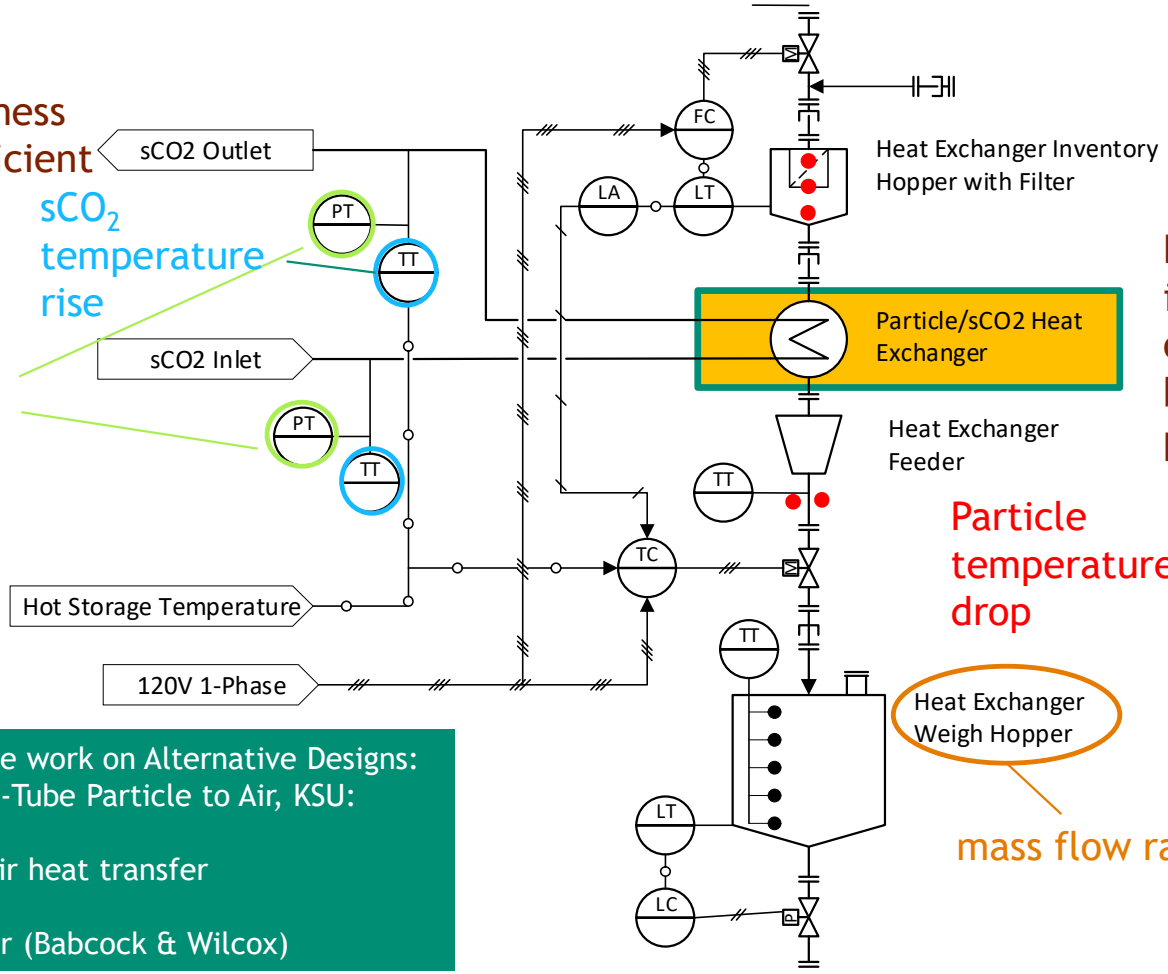


Test Metrics:

- 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

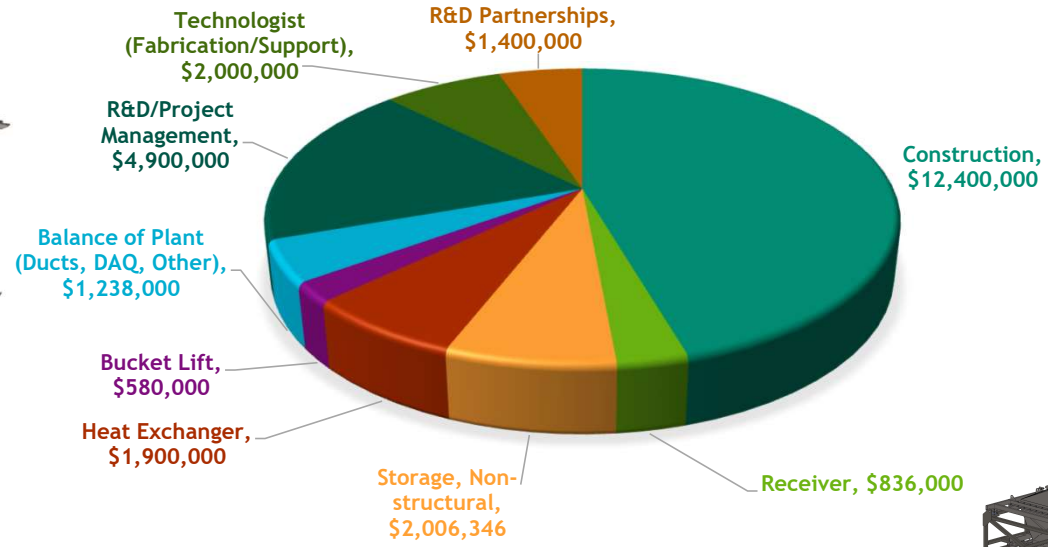
Fluidized-bed heat exchanger (Babcock & Wilcox)

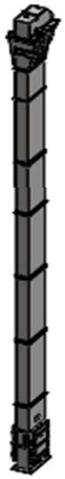
Procurement Process

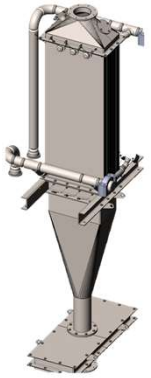
- 10 Subsystems divided into 86 pieces of equipment
- Over 355 part assemblies
- Over 5000 procurements expected including instrumentation

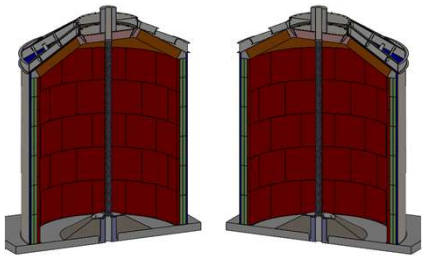
Subsystem	Major Particle Equipment List	Parts/Assemblies	Drawing Number	Description	Model Number	Material	Source of Estimate	Estimate Category	Qty	Min Cost	Nominal Cost	Max Cost	Uncertainty Bounds	Make/Buy	Lead Time (wks.)
900000 Cold Storage Bin $274,788.82	905000 Floor	Slab Cooling Plate	905932	actively 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	Microporo	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	Microporo	Elmlin	Quoted	5	$230	$230	$230	-0%/+5%	Buy	8
		HD Liner Gunite Tuffcrete	906941	Shotcrete application of Tuffcrete material	High-Density Refi	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 Refi	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	Microporo	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	Microporo	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 Support	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 Microporo	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 Valv	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

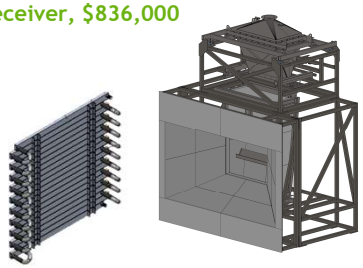
G3P3 Cost Breakdown

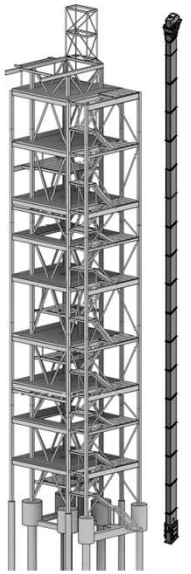












Summary

- Project Duration – 3 yr
  - Tower construction ~18 months
  - Installation of Components in Tower – 6 months
  - Commissioning – 9 months
  - Testing – 3-6 months
- Project Budget - $25M
  - Tower – 50%
  - Components – 25%
  - Staff – 25%
- Major Milestones
  - Determine total energy delivered to sCO_2
  - Characterize system and component performance in a wide variety of environmental conditions and control factors
  - Validate models
  - Log, stream, and archive streaming data 24/7 (external access TBD)

Acknowledgments

- This work is funded in part or whole by the U.S. Department of Energy Solar Energy Technologies Office under Award Number 33869
  - DOE Project Managers: Matthew Bauer, Andru Prescod

Thank you