



# Nuclear Cryogenic Propulsion Stage (NCPS) Task 6: Affordable Development Strategy & Space Capable Cryogenic Thermal Engine

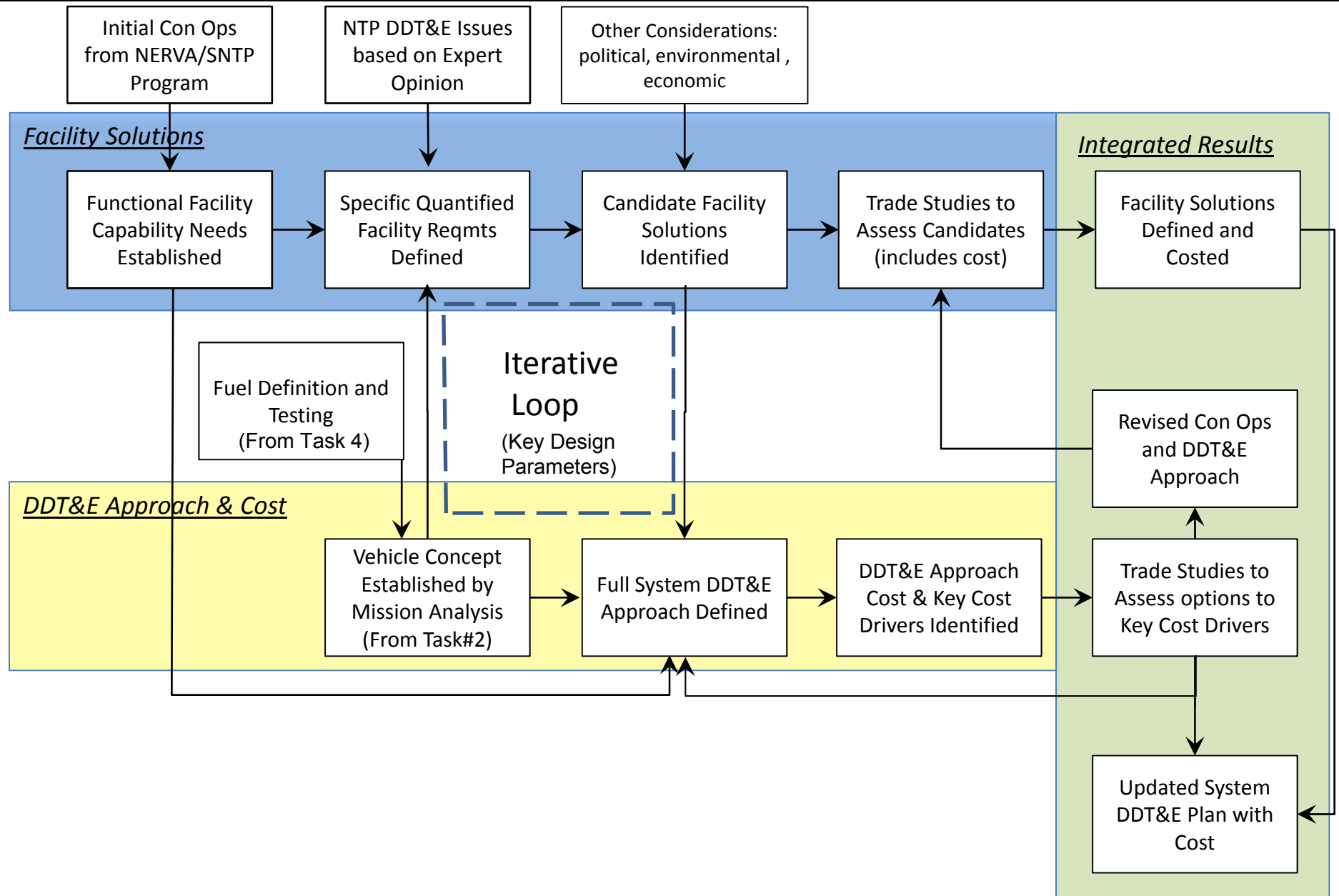
Authors: Harold Gerrish, Jeremy Kenny, David Coote, Libby Creel, and Glen Doughty

# AES NCPS Task 6



- Scope
  - In support of FY14 AES funded, NCPS activities
- Purpose:
  - Establish a methodology for evaluating and estimating technical approaches, cost, and schedule that will be used in further studies in FY15 and beyond.
    - Establish a Nuclear Rocket Engine Development Team
    - Develop Partnerships:
      - Stennis Space Center
      - Center for Space Nuclear Research
      - Glenn Research Center
      - Nuclear Regulatory Commission
      - Department of Energy
  - Establish baselines in the following areas:
    - Approach > Technical Solution
      - Engine Test Facility – Full Containment
      - Low Enriched Uranium(LEU) Engine
    - Cost - Cost-to-design based
    - Schedule - WBS Based, Unconstrained

# Logic Flow





# Work Breakdown Structure (Study)

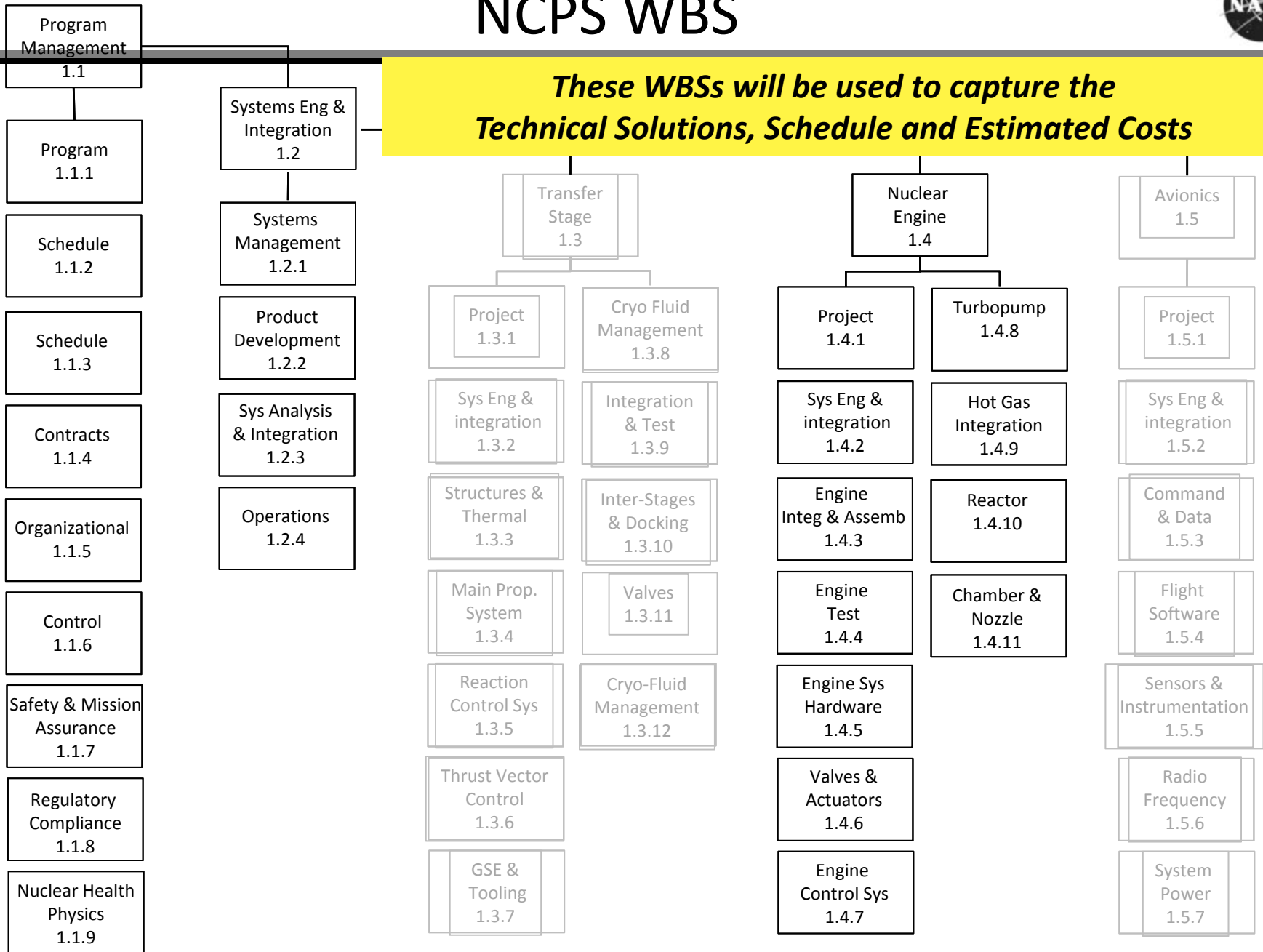






# NCPS WBS

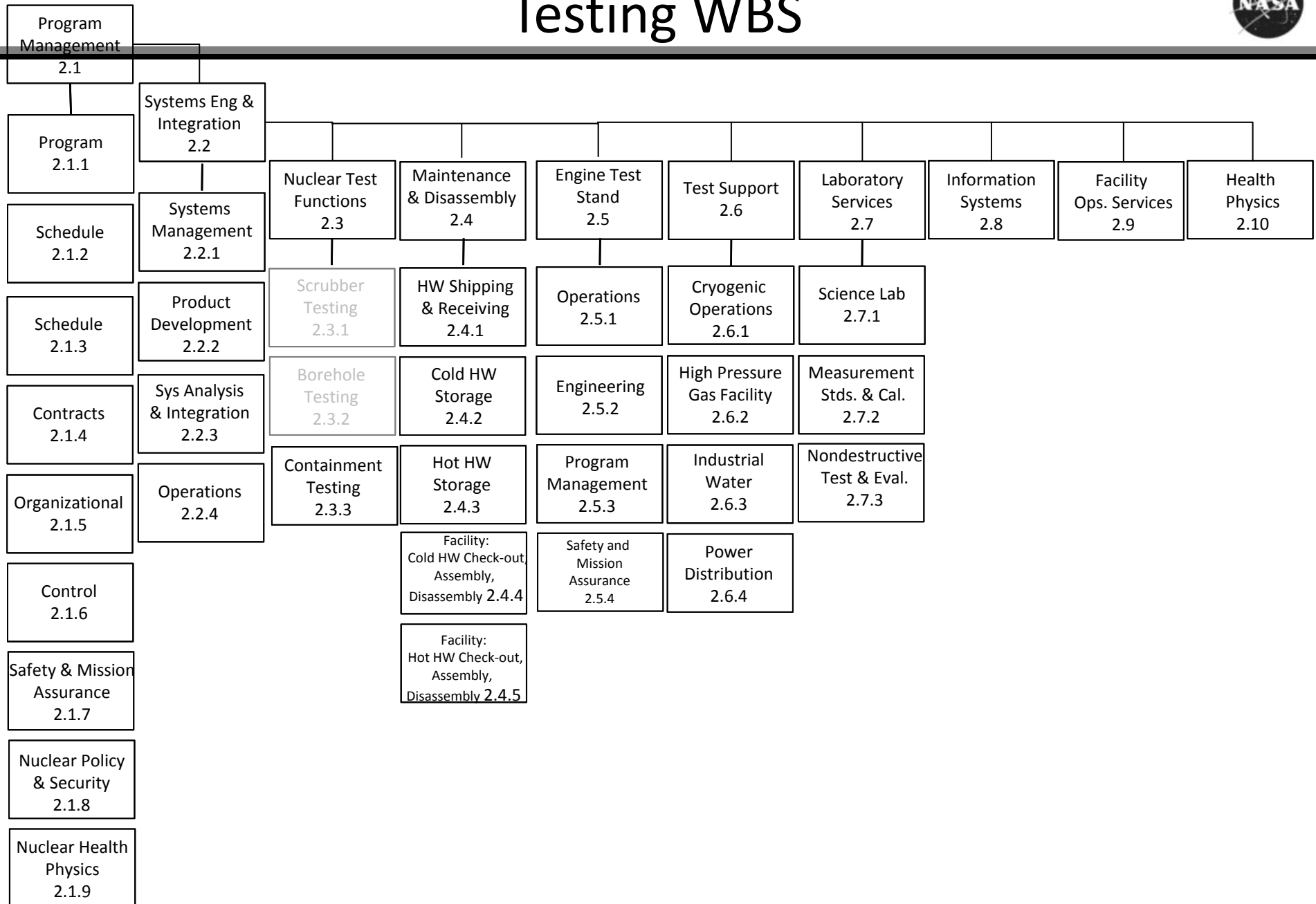
**These WBSs will be used to capture the Technical Solutions, Schedule and Estimated Costs**



*Grey Font indicates that these items were taken out of scope for FY14 Study*

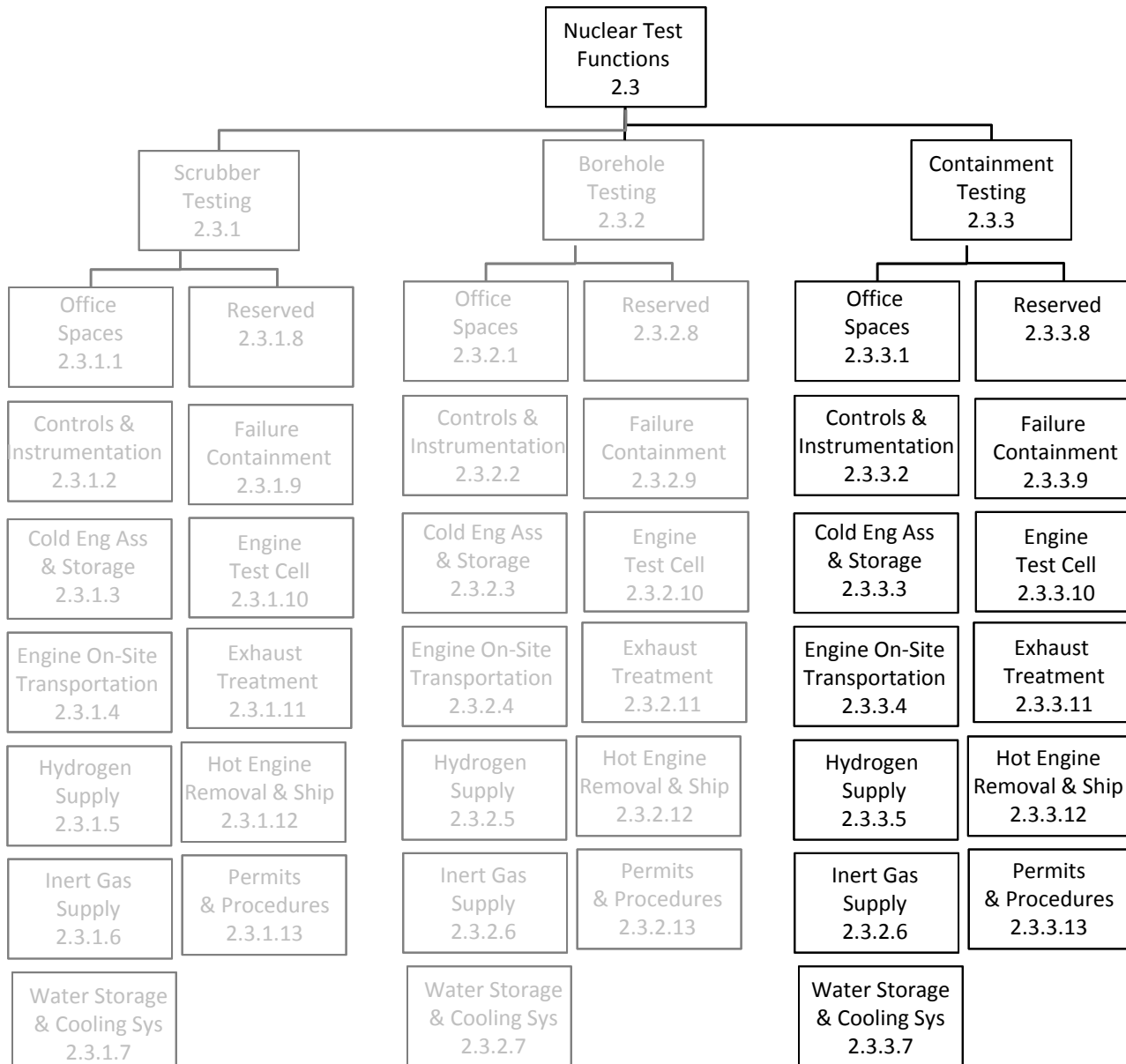


# Testing WBS



*Grey Font indicates that these items were taken out of scope for FY14 Study*

# Testing WBS 2.3 Decomposition



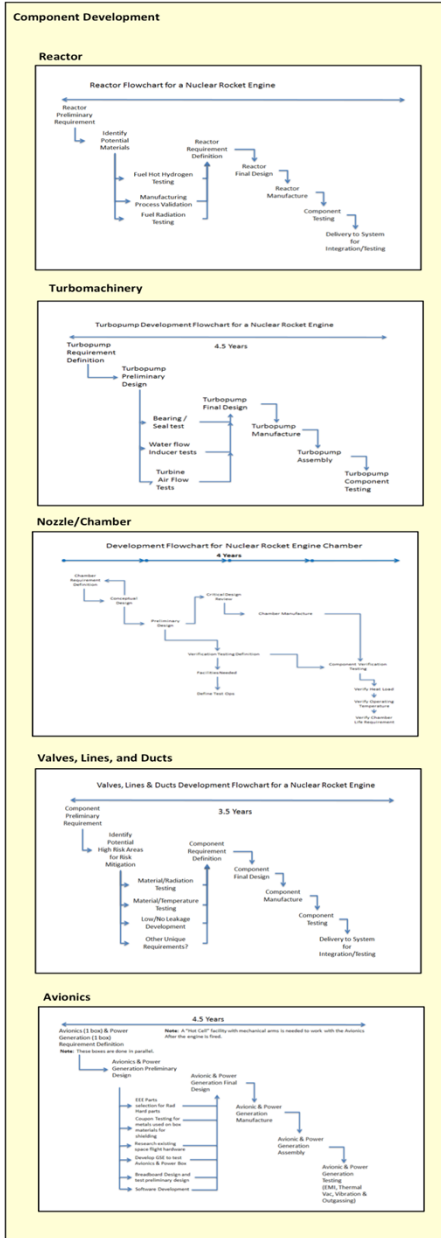
*Grey Font indicates that these items were taken out of scope for FY14 Study*



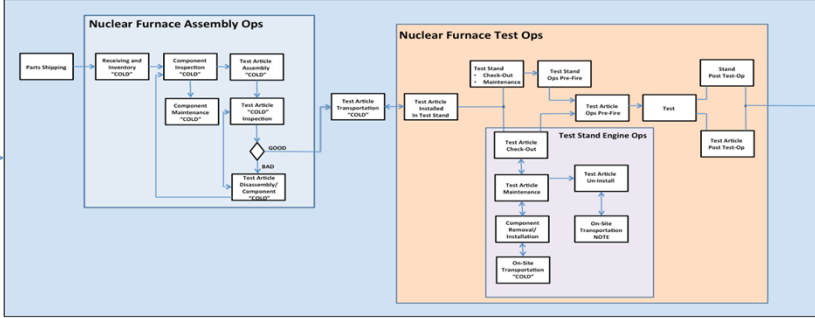


# Concepts of Operations

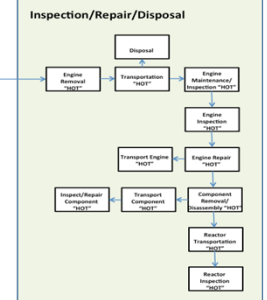
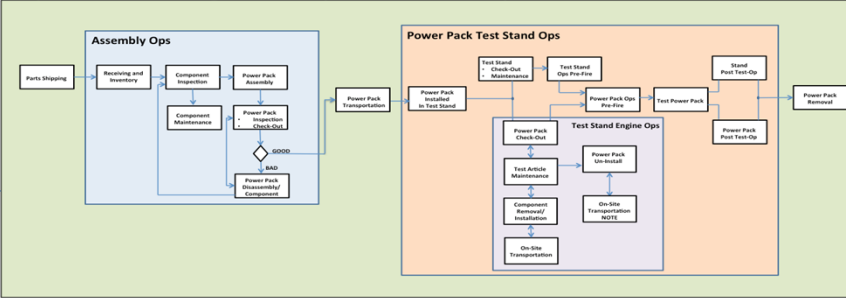
# Single Page Layout of the Con-Ops



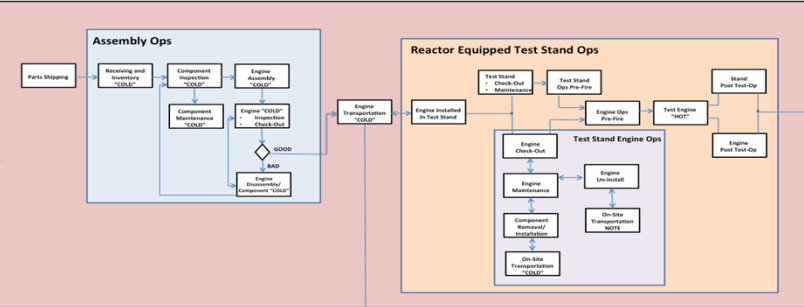
## Nuclear Furnace



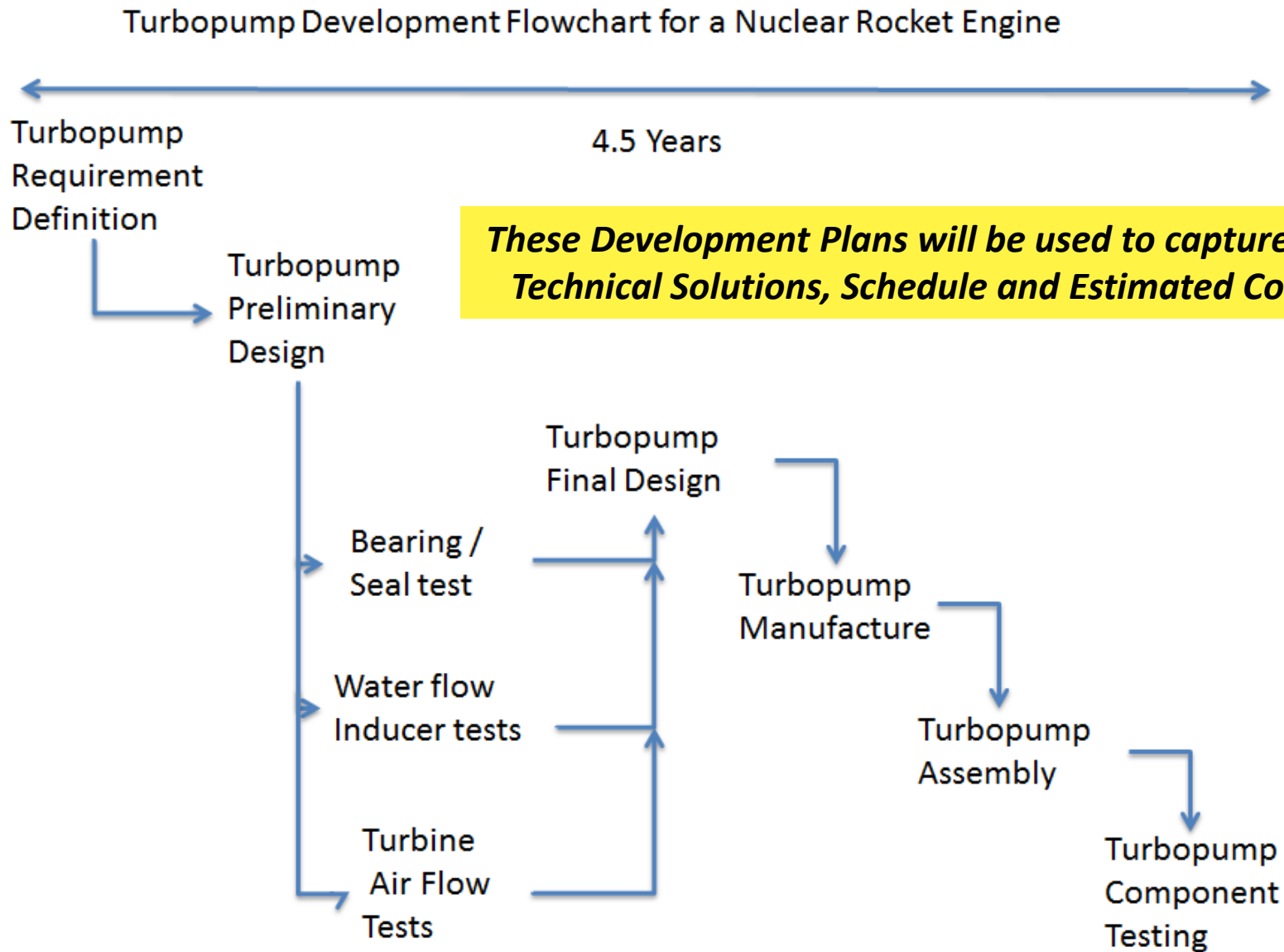
## Liquid Rocket Engine Component Development



## Integrated Engine System Nuclear Hot Development

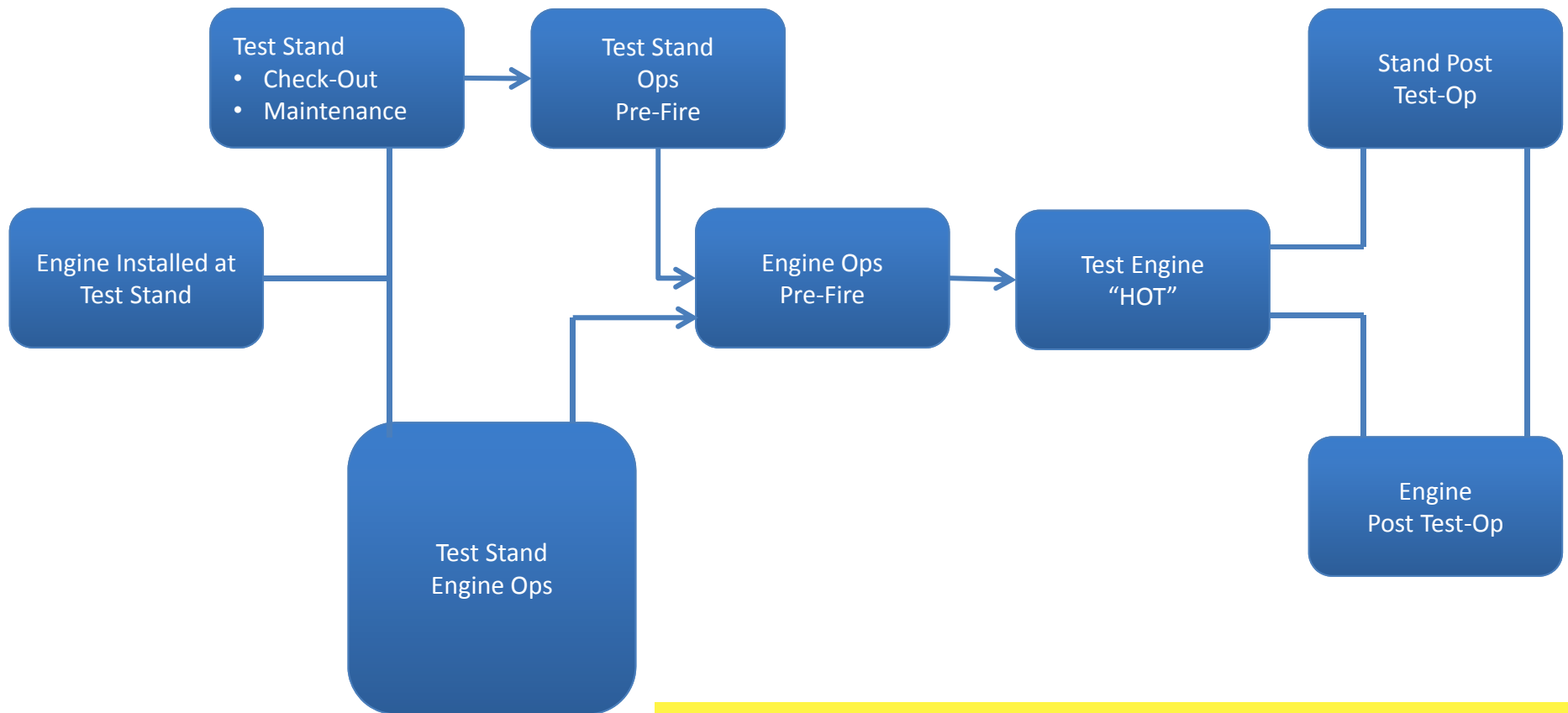


# Example: Component Development - Turbo Machinery



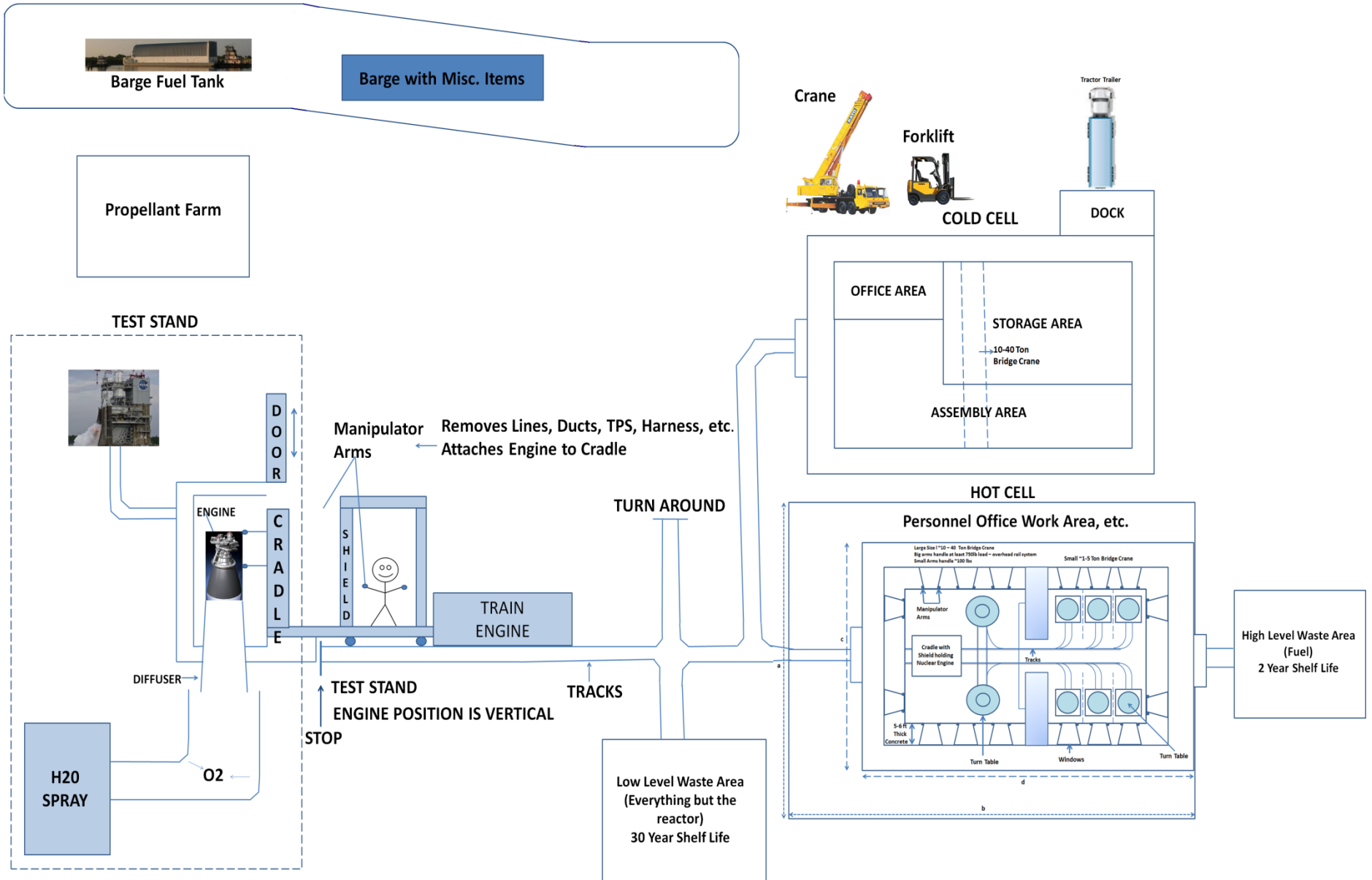


## Reactor Equipped Test Stand Ops

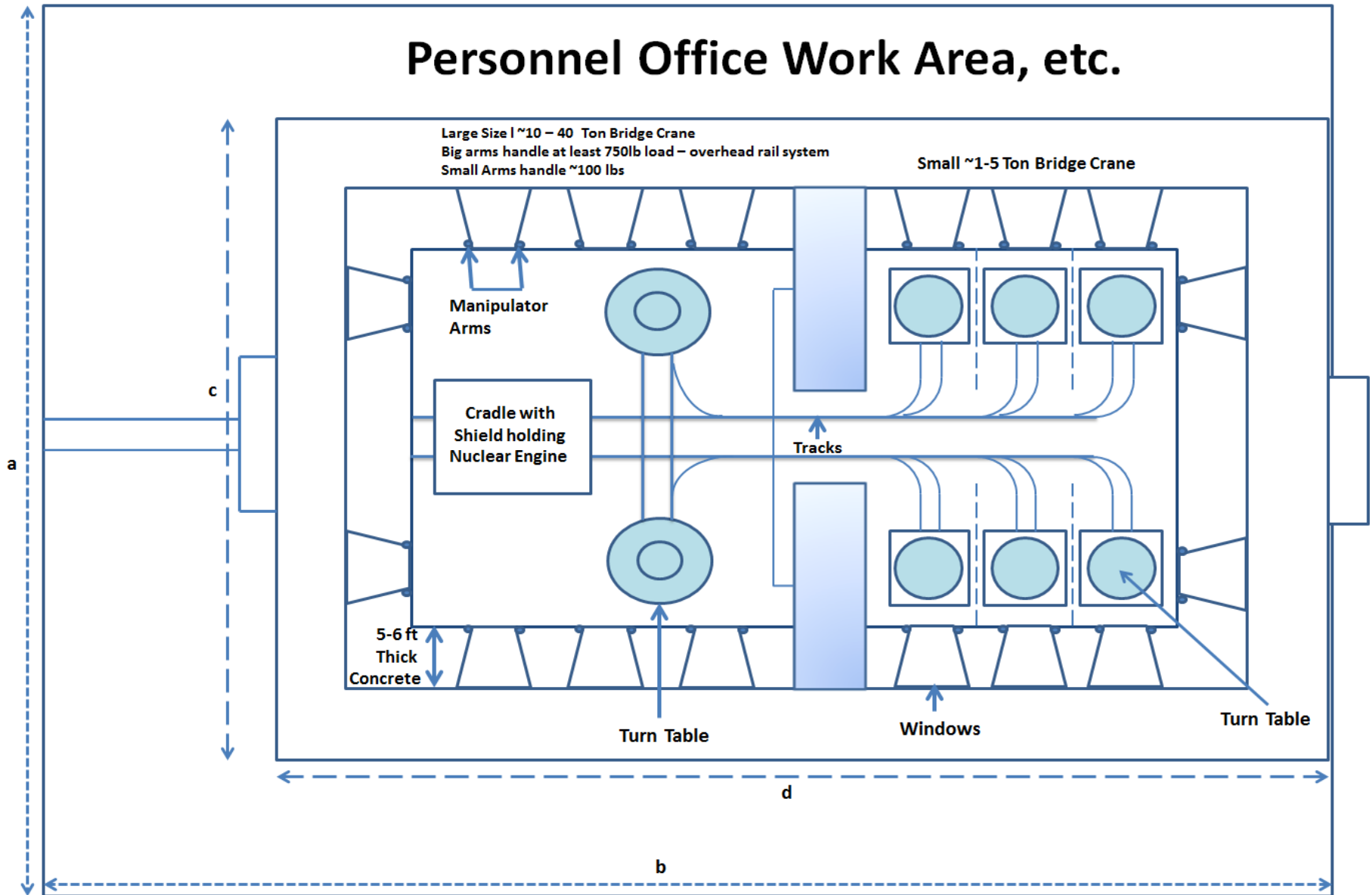


***These Development Plans will be used to capture the Technical Solutions, Schedule and Estimated Costs***

# NCPS AES FY13 Engine Test Con-Ops

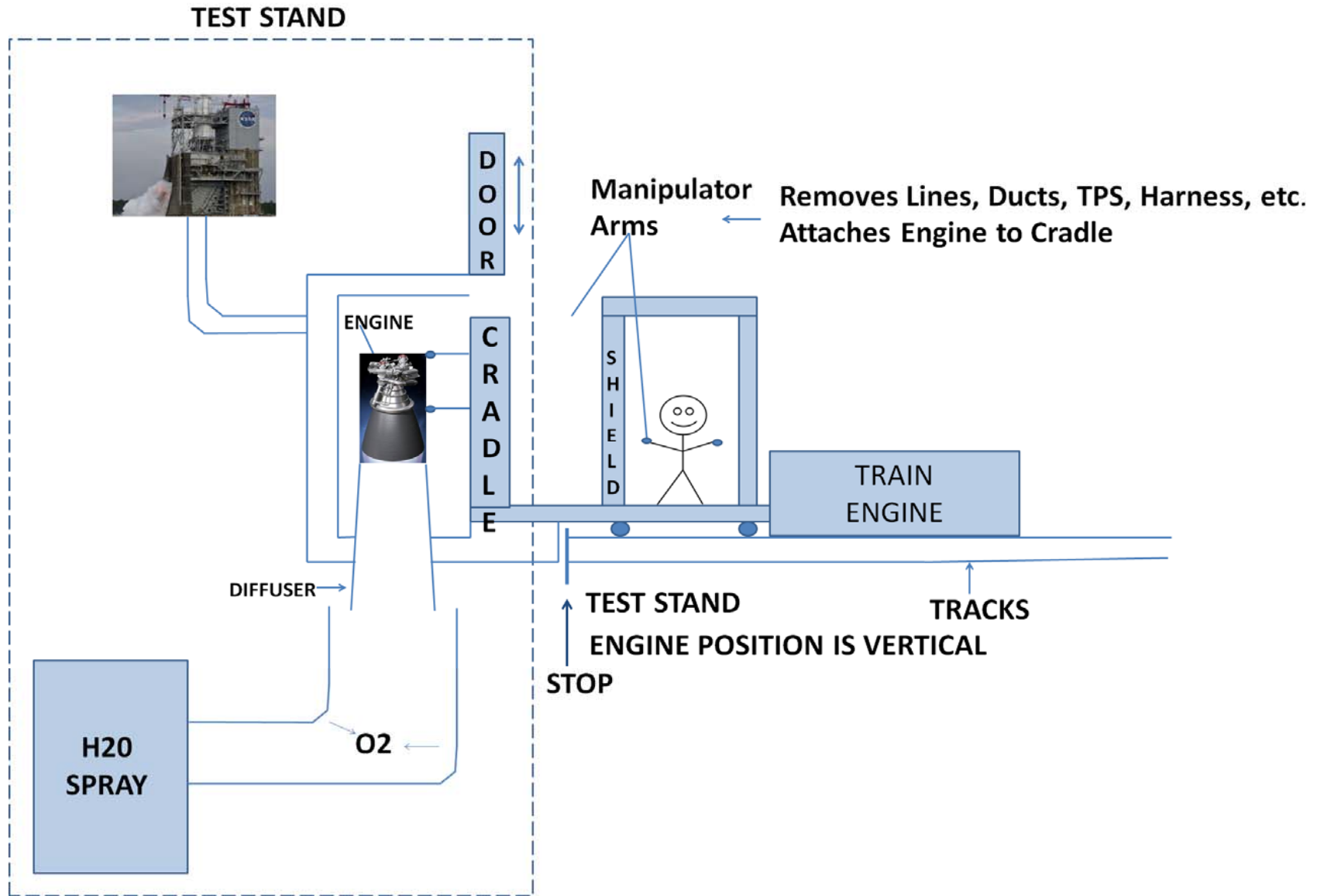


# NCPS AES FY13 Hot Cell Design

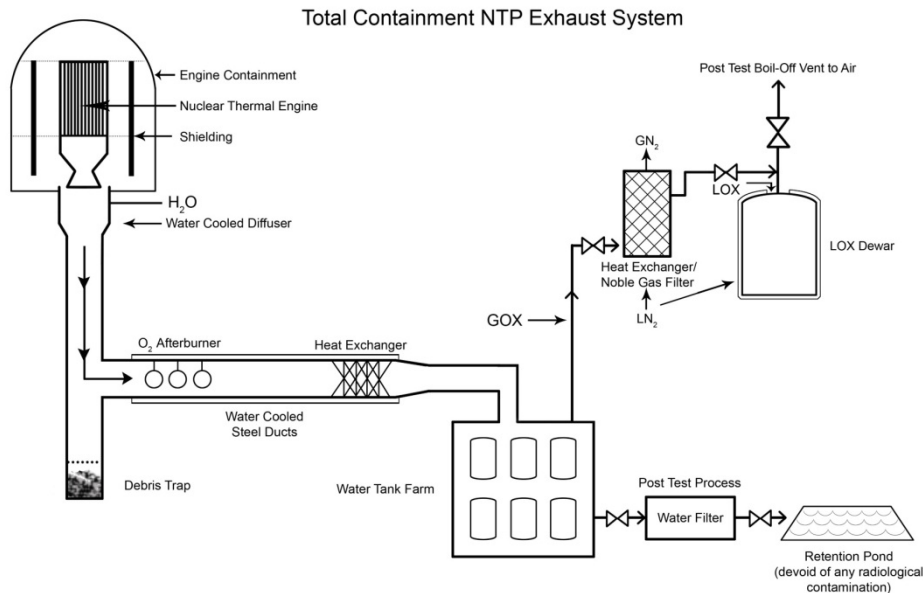




# NCPS AES FY13 Test Stand Operations



# Total Containment NTP Exhaust System



## Strategy:

- Fully contain NTP exhaust during burns
- Slowly drain containment vessels after radiation levels drop to favorable levels
- Subscale test at significant fraction (7%) of system needed for full-thrust NTP testing
- Simulate NTP exhaust with hot hydrogen generator
- Full control over modular system
- Develop maintenance and clean-up approaches

## How it works:

- Hot hydrogen exhaust from the NTP is run into a water cooled diffuser.
- The diffuser transitions the flow from supersonic to subsonic to allow more efficient burning in the afterburner
- O<sub>2</sub> rich afterburner-burns all H<sub>2</sub>; Products include steam, excess O<sub>2</sub> and a small fraction of noble gases (e.g., xenon and krypton)
- Heat exchanger and water spray pulls heat from steam to lower the temperature and condense
- Water tank farm collects H<sub>2</sub>O and radioactive particulates. Drainage is filtered.
- Heat exchanger-cools residual gases to LN<sub>2</sub> temperatures (freezes and collects most noble gases). Starts the flow of LOX
- LOX dewar stores LO<sub>2</sub>. Drainage via boil-off
- Meets any standards/regulations for post test release



# Functional Analysis

# Functional Facility Capability Needs Summary



- Nuclear Engine Specific Test Functions
  - Scrubber Testing
  - Borehole Testing
  - Fully Contained Testing
- Nuclear Engine Maintenance and Disassembly Specific Test Functions
  - Hardware Shipping and Receiving
  - Cold hardware storage
  - Hot hardware storage
  - Facility for cold hardware check-out, assembly, disassembly, inspections
  - Facility for hot hardware check-out, assembly, disassembly, inspections.
- Engine Test Stand
  - Operations
  - Engineering
  - Program Management
  - Safety and Mission Assurance
- Test Support
  - Cryogenic Operations
  - High Pressure Gas Facility
  - Industrial Water
  - Power Distribution
- Laboratory Services
  - Science Lab
  - Measurement Standards and Calibration
  - Nondestructive Test and Evaluation
- Information Systems and Computer Services
- Facility Operational Services
- Health Physics
- E-MAD Type Capabilities
  - Transportation
  - Receiving and Storage
  - Cold Bay
  - Hot Bay
  - Equipment Maintenance
  - Process Cells
  - Hot Hold and Transfer
  - Hot Cells
  - Master Control Room
  - Shops
  - Facility Support Systems
  - Security
  - Decontamination Facilities
  - Shelter Area



# Nuclear Engine Specific Test Functions

- Scrubber Testing
  - Exhaust Containment and Collection
  - Supersonic Diffuser
  - Hydrogen Injection
  - Turning Elbow
  - Subsonic Diffuser
  - Debris Screen
    - Coarse
    - Fine
  - Heat Exchanger
  - Transition Duct
  - HEPA Filter
  - Cryogenic Heat Exchanger
  - Activated Charcoal Nobel Gas Filter
  - Flare Stack
  - H2 Liquefaction
- Borehole Testing
  - Exhaust Containment
  - Supersonic Diffuser
  - Subsonic Diffuser
  - Water Injection
- Containment Testing
  - Exhaust Containment and Collection
  - Supersonic Diffuser
  - Subsonic Diffuser
  - Oxygen Injection
  - Heat Exchanger
  - Turning Elbow
  - Transition Duct
  - Water Tank Farm
  - Water Filter
  - Cryogenic Heat Exchanger
  - Vent

*Grey Font indicates that these items were taken out of scope for FY14 Study*

# Nuclear Engine Maintenance and Disassembly Specific Test Functions

---

- Hardware Shipping and Receiving
- Cold hardware storage
- Hot hardware storage
- Facility for cold hardware check-out, assembly, disassembly, inspections
  - To include component-specific workstations
- Facility for hot hardware check-out, assembly, disassembly, inspections
  - All processes controlled remotely via manipulator arms, cranes, etc.
- Shielded transportation of hot and cold test articles/components between different bays/cells/test stand
- Shielded installation equipment for test stand installation and removal
- Central Control Room
  - Control of manipulators/cranes in hot areas
  - Management of personnel ingress/egress from area to area (shielding doors)
  - Radiation monitoring (gamma, neutron monitors)
  - 24-hour security management
  - Facility Support Systems
- Machine shop, electrical shop
- Decontamination area
- Shielded shelter area for personnel safety during hot article transportation
- Health Physics/Medical area
  
- *Note: More detail is available at the end of this section on the EMAD facility*



# Engine Test Functions

---



- Test Stand Services
  - Operations
    - Touch Labor
    - Maintenance
    - Non-Construction of Facilities Construction
  - Engineering
    - Systems Engineering
    - Analysis and Simulation
    - Configuration Management
  - Program Management
    - Legal/Contracts
    - Schedule
    - Budget
    - Procurement
  - Safety and Mission Assurance

# Propulsion Test Support

---



- Cryogenic Operations
  - Liquid Hydrogen
  
- High Pressure Gas Facility
  - Air Supply Systems
    - Missile Grade
    - Confined Entry
  - Helium Supply System
  - Nitrogen Supply System
  - Hydrogen Supply System
  - Welding and Construction Support
  
- Industrial Water
  
- Power Distribution
  - Nominal Operations
  - Emergency Power Generation

# Laboratory Services

---



- Science Lab Services
  - Environmental Laboratory
  - Gas and Material Science Laboratory
  
- Measurement Standards and Calibration Laboratory
  - Standards Laboratory
  - Dimensional Laboratory
  - Electrical Calibration and Instrument Repair Laboratory
  - Pressure Laboratory
  - Flow Laboratory
  - Mechanical Laboratory
  - Vibration Laboratory
  - Temperature Laboratory
  - Cleaning Laboratory
  - Fabrication and Development Laboratory
  
- Nondestructive Test and Evaluation Laboratory
  - Radiographic Inspection
  - Ultrasonic Testing
  - Liquid Penetrant Testing
  - Magnetic Particle Testing
  - Leak Testing
  - Eddy-Current Testing
  - Visual Inspection
  - Hardness Testing
  - Bubble Leak Testing
  - Test Article Leak Testing

# Information Systems

---



- Software Development
- Applications Systems
- Data Systems and IT Operations
- Telecommunications
- IT Security Services
- Information Resources Management

# Facility Operating Services

---



- **Operating Engineering Services**
  - Engineering Services
  - Documentation
  - Spares Provisioning of Pressure Vessels
  - Construction Services
  - Safety Services
  
- **Facilities Services**
  - Work Processing
  - Facilities Support
  - Maintenance Engineering
  - Carpentry and Paint
  - Equipment Operations
  - Mechanical and Plumbing
  - Electrical inc High Voltage
  - HVAC
  - Custodial Services
  - Roads and Grounds
  
- **Institutional Services**
  - Logistics
  - Institutional Services
  - Information Services
  - Procurement
  - Drayage and Labor
  
- **Technical Services**
  - Construction Management
  - Component Processing Facilities
  - Weld and Fabrication Shop
  - Machine Shop
  - Quality Services
  - Component Support

# Health Physics



- **Full Health Physics Staff**
  - Management/Health Physicists/Technicians
- **Surveillance**
  - Periodic radiological surveys of areas
- **Access/Egress Control**
  - Radiation Work Permits
  - Monitor all items and personnel exiting controlled areas
- **Portable Radiation/Contamination Monitoring**
  - Alpha, Beta, Gamma/X-ray, Neutron Monitors
  - Smears/wipes
- **Fixed Radiation Monitoring**
  - Gamma and neutron monitoring systems
  - Gamma monitoring system for personnel areas adjacent to process areas
  - Gamma monitoring for site boundary
- **Airborne Contamination Monitoring**
  - Portable samplers for personnel monitoring
  - Fixed area monitors
- **Personnel Monitoring**
  - Beta/gamma/neutron dosimetry
  - Hand and foot monitors at access/egress points
  - Whole body counter for determining internal deposition



# Health Physics



- **Counting Lab**
  - Smear/wipe and air sample counters/scalers
  - Multichannel analyzer for isotopic determination of air samples and smears/wipes
- **Training**
  - Initial and periodic radiation safety training for all site staff
- **Emergency Monitoring**
  - Plume tracking
  - Surface airborne/radiation monitoring
  - Soil/vegetation monitoring
- **Decontamination**
  - Personnel
  - Portable items
  - Areas and fixed items
- **Shipping /Disposal**
  - Packaging
  - Shipping papers
- **Training**
  - Initial and periodic radiation safety training for all site staff



# Nuclear Cryogenic Propulsion Stage (NCPS) Space Capable Cryogenic Thermal Engine

# Space Capable Cryogenic Thermal Engine Task



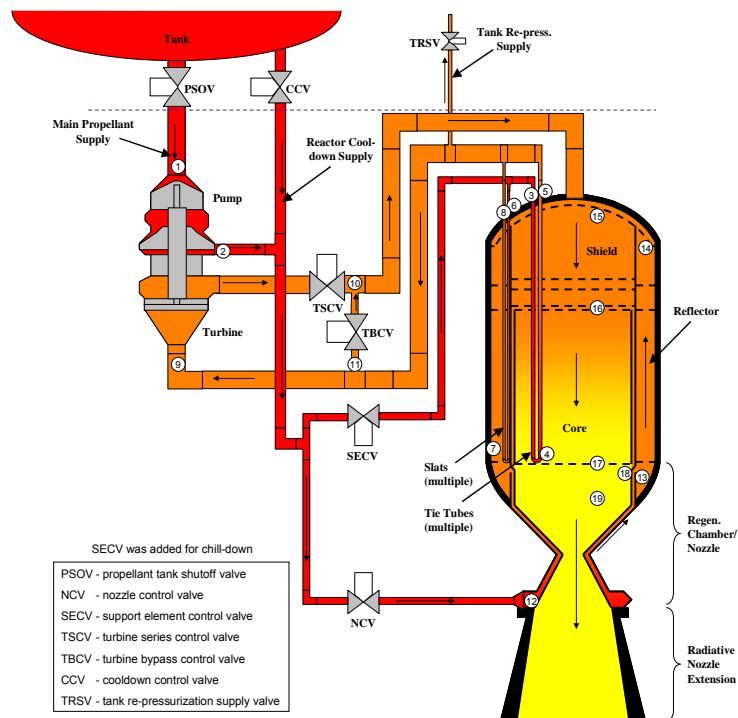
- **NCPS has begun effort to mature an engine design to aid:**
  - Low enriched uranium (LEU) engine cycle identification which can satisfy various mission applications
  - Directed choice of reactor fuel(s) to help drive and shape fuel development and testing
  - Matured inputs into Development Planning efforts
- **Effort known as the Space Capable Cryogenic Thermal Engine (SCCTE) study**
  - Effort based within context of Pre-Phase A / Phase A life-cycles; but not formally anchored to all Pre-Phase A / Phase A study attributes
- **SCCTE effort occurring over three main phases in FY14**
  - System Requirements Establishment and Engine Cycle Trades
    - Size NTP engine that satisfies vehicle mission requirements
    - Top-level reactor design and engine system cycles are traded down and selected
    - Mainstage operation considered
  - Preliminary Engine System Concept Design
    - Refine NTP engine design with inputs from rocket engine component engineers
    - Top-level reactor design and engine cycle features are finalized
    - Mainstage and transient operations considered
  - Final Engine System Concept Design
    - Engine component designs are matured to a SDR level
    - Engine outer mold line defined
    - Mainstage and transient operations considered
    - Technical development challenges and associated risk mitigation work for development efforts defined

# SCCTE Task Products

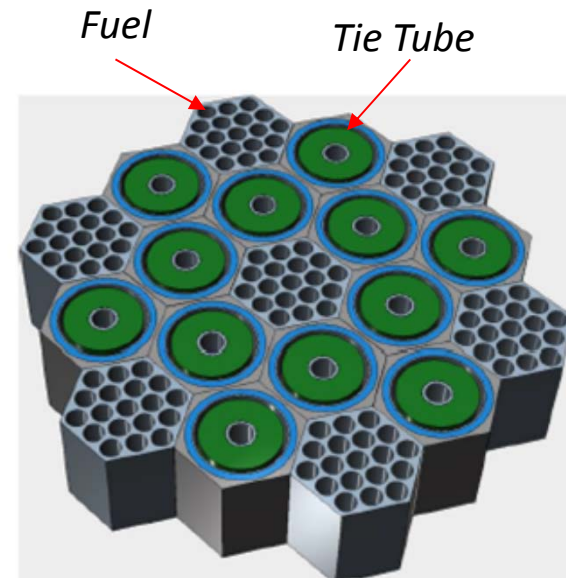


- **Conceptual Engine Design, Power Balance, and System Requirements**
  - Engine system analysts working with nuclear thermal reactor designers to select engine cycle, power balance, and reactor characteristics to deliver NTR performance values
    - Thrust ~ 25,000 lbf; Isp ~ 900 sec
    - Weight and size determined from vehicle mission studies
  - Engine power balance and reactor design will mature to consider both mainstage and transient operation
  - Engine Integration Considerations, Con Ops
  - Status: engine cycle selected as closed expander, tie-tube design; initial reactor sizing completed

*Closed Expander Engine Cycle  
Turbine Enthalpy from Tie Tubes*



*Notional Reactor Lattice  
for LEU Materials (from CSNR)*



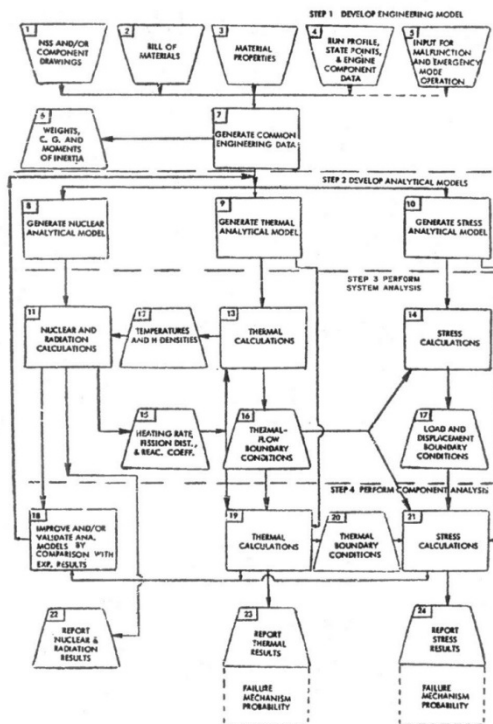
# SCCTE Task Products (cont.)



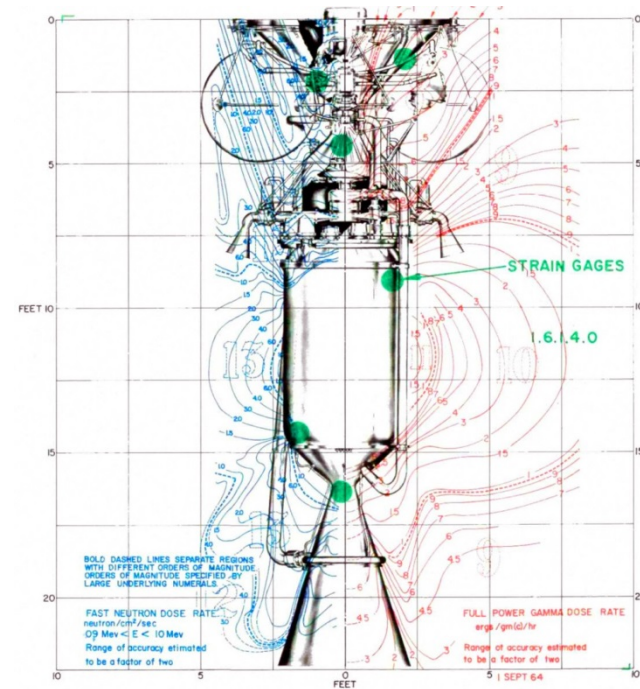
- **Engine Analysis Approach Plan**

- Identification of traditional and unique analysis needs for NTR engine design and certification
  - Review standards from 'terrestrial' nuclear thermal reactors to identify applicability to rocket designs
  - Important to address design margin and metrics (e.g., factors of safety)
  - Stress / structural dynamics, fluid dynamics, internal and external thermal environments, radiation
- Need to address analysis approaches to engine CDR level
- Status: Reviews of historical and current nuclear reactor design approaches ongoing

## Historical Analyses Approach Plan from NERVA



## NERVA Engine Predicted Radiation Pattern



# SCCTE Task Products (cont.)



- **Materials Characterization and Development Plan**

- Understand NTR-relevant material options and existing databases
- Identification of knowledge gaps in material capability based on projected engine operation
- Develop material characterization plan to eliminate knowledge gaps for future NTP engine development
- Status: Existing materials database compiled; working towards addressing future needs.

- **Component DDT&E Plans**

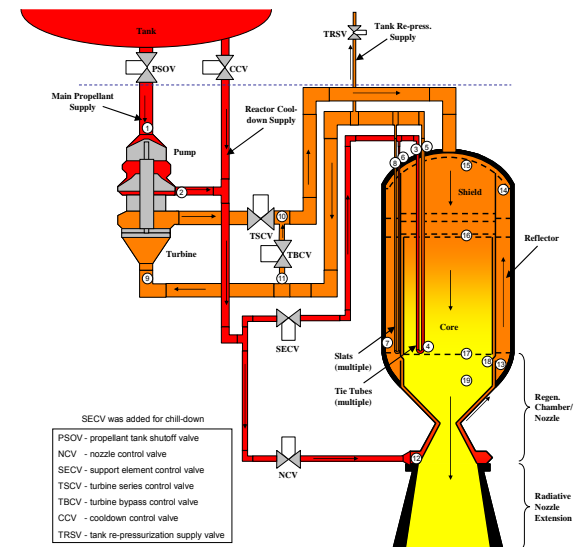
- Develop engine component development plans based on concept design work and understanding with nuclear-specific testing requirements

- What materials do we use?
- What analyses do we need?
- How do we test these components?
- What are the in-space operation issues?

- Engine components include:

- Reactor
- Chamber and nozzle
- Turbopump
- Valves, ducts, and lines
- TVC system
- Startup / shutdown pressurization systems
- External shield
- Avionics / controllers

*SCCTE Engine Cycle  
With Major Components  
Identified*



- Identify Key Design Requirements, engine cycle demands, conceptual designs, and development work

- Status: Reviews of prior NTR engine component developments ongoing; initial sizing beginning with engine power balance definition.





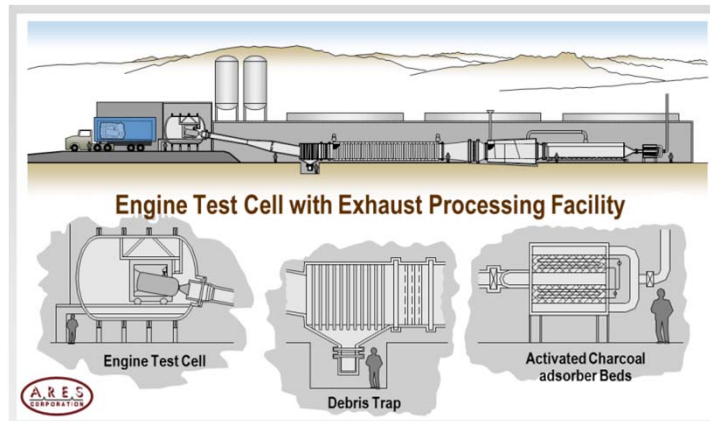
---

# Back Up Sides

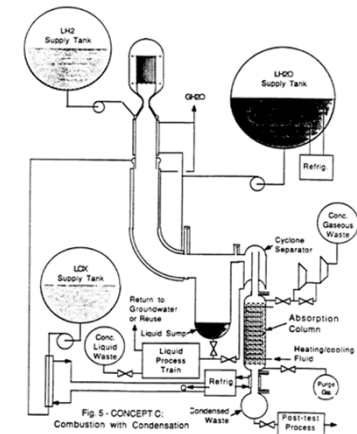
# NTP Ground Test Options



Bore hole



Above ground scrubber with filters



Total containment with combustion and condensation

- ◆ Bore Hole
  - Collected past test reports from Nevada Test Site showing significant effects of water saturation, turbulent flow rate, hole depth, and pressures on soil permeability.
- ◆ Above Ground Scrubber
  - Nuclear Furnace (NF-1) ground test scrubber of Rover/NERVA appears successful
  - Collected other past studies looking at exhaust filtering before flaring the hydrogen
  - Obtained nuclear filter info
    - DOE and ASME standards for nuclear air cleaning and gaseous waste treatment
    - How long to get new filter licensed and by who.
- ◆ Total Containment
  - Initial analysis results show hydrogen exhaust can burn at high temperatures with oxygen and produce steam to be cooled, condensed, and collected.



# Nuclear Cryogenic Propulsion Stage (NCPS)

## Task 6.0

### SME Issues

# NTP DDT&E Issues based on Expert Opinion

---



## Initial Con Ops from Rover/NERVA/SNTP Programs

- How to best transport a fully assembled NTP engine?
- Any special tests needed to license ground transportation? Include how to transport/dispose of hot engine components after examination.
- Is the final fuel design and fabrication going to be classified? This could affect engine assembly and disassembly.
- Where is best for engine assembly and acceptance test? Who is responsible?
- What is going to be acceptance testing? Is zero power criticality required?
- How long does it take to manufacture various engine components (e.g. fuel elements) for subsystem and system tests? Long lead components affect development schedule.

# NTP DDT&E Issues based on Expert Opinion

---



## Functional Facility Capability Needs Established:

- Is a special power pack facility needed? What are the requirements?
- Is a special turbopump facility needed? What are the requirements?
- Can a space reactor facility be designed to accommodate NTP, NEP, FSP, Bi-modal? Recommend two cells for short and long duration testing.
- Can the full scale engine cold flow test facility be at MSFC?
- List the current irradiation facilities to consider and what are the capabilities, pro's/con's of each?
- If some of the performance requirements need a prototype flight test to qualify, should we include the flight demo as a functional capability and what do you get from it?
- How much disassembly is required to breakdown a hot engine for shipment to hot cells for close examination? How hot can the parts be for loading into special cask?

# NTP DDT&E Issues based on Expert Opinion

---



## Specific Quantified Facility Reqmts Defined:

- Start off with factors of safety (FOS) from liquid rocket engines and solid rocket motors. Future management could reduce the FOS and accept the risk.
- Does an NTP standard need to be worked before ATP with NTP development? What committee is needed?
- We need a breakdown of the facility operating requirements for each candidate.
- Can a short burn time NTP be run again after minor repairs?
- Guidelines from DOE needed to determine the facility requirements for reactor development.
- Combine the engine design performance requirements with the human rated standards and guidelines to determine the facility requirements for each ground test.



## Other Considerations:

- Who has a model to best determine how much noble gas can be released and not exceed NEPA standards?
- Determine the amount of filtering required based on NEPA and test site location.
- How long to wait after engine firing before engine can be transported or repaired? Is a graph possible showing radiation level vs time with a red line indicating acceptable level?
- Allowed dosages to the work force? Correlate to long life facility radiation expectations.
- When to have public meetings at sites requiring EIS?

## *E-MAD Capabilities (additional detail)*



- **Railroad Transport System**
  - Manned Control Car – provides electrical power and compressed air for installation and removal of engine from the test facility
    - Shielded control cab
  - Engine Installation Vehicle – installs, removes, and transports engine, has tilt/positioning functions
  - L-3 – locomotive, prime mover for railroad transportation system, controlled from the Manned Control Car
    - Train Includes spacer cars, flatcars, special test cars, and reactor shipping instrumentation cars (controlled environment, power, lighting, equipment mounts)
  
- **Receiving and Storage**
  - Bonded hardware storage room
  - Security vault
  - Tool crib, storage racks & cabinets
  - Airlock entry way
  
- **Cold Bay**
  - Railroad tracks with a 360-degree turntable for rotation of transport cars to off-load onto an auxiliary transport
  - 40-ton bridge crane
  - Access to electrical and machine shops, receiving and storage area



## *E-MAD Capabilities (additional detail continued)*



- **Hot Bay**
  - High bay with concrete shield walls, lead glass viewing window
  - Tracks for entrance & exit of rail transport system
  - Has same 360-degree turntable capability as the Cold Bay
  - Handling systems designed for assembly and disassembly operations via remote manipulator system
  - Handling Systems include:
    - Wall-mounted
    - Floor-mounted
      - Portable turntables, mobile carriage, railroad dolly
    - Overhead positioning system
      - Traveling bridge, carriage, telescoping mast, auxiliary manipulator
  - Post Operative Cell Material Transfer System
    - Transfer between cells
  - Periscopes for inspection and photographs
  - Shielded storage pit below the hot bay floor
  - Shielded door air-lock for transport in and out

## *E-MAD Capabilities (additional detail continued)*



- **Equipment Maintenance**
  - Maintenance of the crane, overhead positioning system, manipulators, and other support equipment performed in a concrete-shielded area adjacent to the hot bay
  
- **Process Cells**
  - Shielded
  - Used for disassembly of the reactor core
  - Operations performed using remote manipulators and overhead cranes
  - Operations viewed through shielded viewing windows
  - Steel shield door isolates the cell
  
- **Hot Hold and Transfer Tunnel**
  - Connects the hot bay to the disassembly and examination cells
  - Serves as a holding and transfer area for radioactive components
  - Visual observation provided by closed-circuit TV
  
- **Hot Cells**
  - 12 hot cells
  - Special car for moving material

## *E-MAD Capabilities (additional detail continued)*



- **Master Control Room**
  - Management control center for all hot areas
  - Control of overhead crane, overhead positioning system, wall-mounted and floor-mounted handling systems, shielding doors, swing-out rails and turntables
  - Communication and visual systems
  - Controls all personnel and equipment access doors
    - Each access point consists of two shielding doors, and only one can be opened at a time
  
- **Shops**
  - Machine shop, welding shop, electrical shop
  - Capabilities for normal facility equipment fabrication, check-out, maintenance, repair, overhaul
  - Spare parts for all specialty equipment (manipulators, cranes, rail system, etc)



- **Facility Support Systems**
  - Hot water boilers for emergency power generation
  - Underground facility air compressors, conditioning, refrigerators, facility vacuum pumps and chilled water distribution, heating, ventilation, etc. controlled by a central underground control room
  - Electrically and radiation shielding work center for rad safe swipe and sample counting
  - HVAC consists of filtration systems for removal of radioactive particulate prior to release through two exhaust stacks
    - Air exhausted from hot areas is filtered to remove all particulate larger than 0.3 microns
    - Hot air handling is separated from cold air handling to prevent radioactive contamination in cold areas
  - Liquid waste system
    - Radioactive waste piped to waste holdup tanks or to a tile field (includes floor drains from all shielded areas)
  
- **24-hour security personnel**
  
- **Health physics office**
  - Management of personnel health

## *E-MAD Capabilities (additional detail continued)*



- **Radiation Monitoring**
  - Neutron monitoring system
  - Gamma monitoring system for process areas
  - Gamma monitoring system for personnel areas adjacent to process areas
  - Embedded sampling systems
- Each radioactive source has a portable neutron monitor which travels with the source, provides remote read-out
- Fixed gamma detectors in processing areas that provide remote read-out, supplemented with portable gamma detectors
- Hand and foot counters at access points into the process areas
  
- **Decontamination facilities**
  - Rail system
  - High pressure water
  - Steam cleaner
  - Chemical cleaning tanks
  
- **Shelter Area**
  - Shielded area for personnel safety during external transport of hot test articles

# Schedule



ID	Task Name	Start	Finish	% Complete	Tr 4, 2012		Qtr 1, 2013			Qtr 2, 2013			Qtr 3, 2013			Qtr 4, 2013			
					Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	
1	<b>NCPs Engine Development</b>	<b>9/3/13</b>	<b>8/29/14</b>	<b>2%</b>															
2	<b>Review Milestones</b>	<b>1/31/14</b>	<b>8/29/14</b>	<b>0%</b>															
3	Review 1	1/31/14	1/31/14	0%															
4	Review 2	4/30/14	4/30/14	0%															
5	Review 3	8/29/14	8/29/14	0%															
6	<b>Task 2 Pre-Conceptual Design</b>	<b>11/1/13</b>	<b>8/29/14</b>	<b>0%</b>															
7	Preliminary Engine Requirements	11/1/13	11/14/13	0%															
8	Lock Down FY14 Study Engine Requirements	11/1/13	12/2/13	0%															
9	Preliminary FY Study Mission Profile	11/1/13	11/14/13	0%															
10	Lock Down FY Study Mission Profile	11/1/13	12/2/13	0%															
11	<b>Task 2.X Preconceptual Design</b>	<b>11/1/13</b>	<b>8/29/14</b>	<b>0%</b>															
12	SCCTE Team Training Course	12/2/13	12/2/13	0%															
13	<b>SCCTE GR&amp;A</b>	<b>11/1/13</b>	<b>3/31/14</b>	<b>0%</b>															
14	MPS& Engine Element Initial Requirements from Mission	11/1/13	12/2/13	0%															
15	Design & Operational Requirements from Task 6	11/27/13	11/27/13	0%															
16	Design & Operational Requirements Revisions to Task 6	3/31/14	3/31/14	0%															
17	<b>Preliminary Engine System Design</b>	<b>11/1/13</b>	<b>8/29/14</b>	<b>0%</b>															
18	MPS Mission Based Design Requirements	11/1/13	1/31/14	0%															
19	Cycle Downselect for SCCTE	11/1/13	1/31/14	0%															
20	Baseline Engine Cycle Design	12/2/13	7/14/14	0%															
21	Steady State Eng. Model	2/3/14	8/1/14	0%															
22	Transient Analysis	2/3/14	8/29/14	0%															
23	Preliminary Reactor (Rx) Design	2/3/14	8/29/14	0%															
24	Schematic	2/3/14	8/29/14	0%															
25	Design Points	2/3/14	8/29/14	0%															
26	Engine OML CAD	2/3/14	8/29/14	0%															
27	Engine Mass Estimates	2/3/14	8/29/14	0%															
28	Engine FY14 SRD & Design Description	7/31/14	7/31/14	0%															
29	<b>Analysis Approach Plan</b>	<b>11/1/13</b>	<b>8/29/14</b>	<b>0%</b>															
30	Analysis Approach Plan (PDR)	11/1/13	1/31/14	0%															
31	Analysis Approach Plan (CDR)	2/3/14	4/30/14	0%															
32	Final Analysis Approach Plan	5/1/14	8/29/14	0%															
33	Analysis Approach - Institutional Needs	5/1/14	8/29/14	0%															
34	Analysis Capability Development Costs	5/1/14	8/29/14	0%															
35	Analysis Approach Plan FY14 Final Report Input	7/31/14	7/31/14	0%															

# Schedule



ID	Task Name	Start	Finish	% Complete	tr 4, 2012		Qtr 1, 2013			Qtr 2, 2013			Qtr 3, 2013			Qtr 4, 2013		
					Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
36	<b>Engine &amp; Component Conceptual Designs &amp; DDT&amp;E Inputs</b>	11/1/13	8/29/14	0%														
37	Component Development Requirements - Facility	11/1/13	1/31/14	0%														
38	Component Requirements Category List (KDRs)	11/1/13	1/31/14	0%														
39	Component Dev. Needs (TRL)	2/3/14	4/30/14	0%														
40	Final Component Requirements with KDRs Specified	2/3/14	4/30/14	0%														
41	Component DDT&E Plan Inputs	5/1/14	8/29/14	0%														
42	Component Conceptual Designs	5/1/14	8/29/14	0%														
43	Component DDT&E FY14 Final Report Input	7/31/14	7/31/14	0%														
44	Engine DDT&E Schedule	5/1/14	7/31/14	0%														
45	<b>S&amp;MA Plan Inputs</b>	11/1/13	7/11/14	0%														
46	Material Characteristic Inputs	11/1/13	1/31/14	0%														
47	Preliminary Material Gap Analysis - Component	2/3/14	4/30/14	0%														
48	Preliminary Material Characteristic Dev. Plan	2/3/14	4/30/14	0%														
49	Final Material Gap Analysis - Component	5/1/14	7/11/14	0%														
50	Final Material Characteristic Dev. Plan	5/1/14	7/11/14	0%														
51	<b>Task 6 Affordable Dev. &amp; Qual Strategy</b>	9/3/13	8/29/14	7%														
52	<b>Stennis Space Center (SSC)</b>	11/1/13	5/29/14	0%														
53	Borehole Concept	11/1/13	1/31/14	0%														
54	Requirements Complete	12/2/13	12/2/13	0%														
55	Technical Assessment Complete	12/31/13	12/31/13	0%														
56	Borehole Design Concept	1/6/14	1/31/14	0%														
57	Self Contained Concept	11/1/13	1/31/14	0%														
58	Requirements Complete	12/2/13	12/2/13	0%														
59	Technical Assessment Complete	12/31/13	12/31/13	0%														
60	Self Contained Design Concept	1/6/14	1/31/14	0%														
61	Flair Concept	11/1/13	1/31/14	0%														
62	Requirements Complete	12/2/13	12/2/13	0%														
63	Technical Assessment Complete	12/31/13	12/31/13	0%														
64	Flair Design Concept	1/6/14	1/31/14	0%														
65	Site Infrastructure Shortfall analysis	2/3/14	3/3/14	0%														
66	Site Infrastructure Cost Estimate	3/4/14	4/30/14	0%														
67	Borehole Design Cost Estimate	2/3/14	4/30/14	0%														
68	Borehole Design Development Schedule	3/4/14	5/29/14	0%														
69	Self Contained Design, Cost Estimate	2/3/14	4/30/14	0%														



# Schedule



ID	Task Name	Start	Finish	% Complete	tr 4, 2012		Qtr 1, 2013			Qtr 2, 2013			Qtr 3, 2013			Qtr 4, 2013		
					Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
70	Self Contained Design Development Schedule	3/4/14	5/29/14	0%														
71	Flair Design Cost Estimate	2/3/14	4/30/14	0%														
72	Flair Design Development Schedule	3/4/14	5/29/14	0%														
73	<b>Marshall Space Flight Center (MSFC)</b>	<b>9/3/13</b>	<b>8/29/14</b>	<b>13%</b>														
74	Test Cell Preliminary Design	11/1/13	11/27/13	0%														
75	Test Stand Disassembly Design	11/1/13	11/27/13	0%														
76	Test Stand Facility Design Requirements	10/21/13	11/1/13	0%														
77	Engine Cost Margin approach	11/1/13	1/31/14	0%														
78	NCPS DDT&E Final Study Report Outline	11/1/13	1/31/14	0%														
79	GSE Logistical Equipment List	11/1/13	11/27/13	0%														
80	Preliminary S&MA Plan	11/1/13	11/27/13	0%														
81	Preliminary Con Ops	9/3/13	11/1/13	100%														
82	Preliminary Facility Function	9/3/13	11/1/13	100%														
83	Preliminary WBS (Joint Product w/ Task 2.X)	9/3/13	11/1/13	0%														
84	Preliminary Cost Estimate (Joint Product w/Task 2.X & SSC)	11/4/13	1/31/14	0%														
85	Preliminary DDT&E Final Study Report Outline	11/1/13	1/31/14	0%														
86	Engine Test Requirements	12/9/13	12/13/13	0%														
87	Update S&MA Plan	7/14/14	8/1/14	0%														
88	Update Con Ops	3/31/14	4/30/14	0%														
89	Updated WBS	3/31/14	4/30/14	0%														
90	Updated Cost Estimate	3/31/14	4/30/14	0%														
91	GSE Cost Estimate	2/3/14	4/30/14	0%														
92	NCPS DDT&E Approach	8/4/14	8/22/14	0%														
93	NCPS DDT&E Schedule	8/4/14	8/22/14	0%														
94	NCPS DDT&E Cost	8/4/14	8/22/14	0%														
95	NCPS DDT&E Sensitivities	8/4/14	8/22/14	0%														
96	NCPS DDT&E Open Issues	8/4/14	8/22/14	0%														
97	<b>NCPS DDT&amp;E Final Study Report</b>	<b>8/18/14</b>	<b>8/29/14</b>	<b>0%</b>														