Hotfire 11 Test Procedure

Important Links

- Hotfire Packing List

Before Leaving RFS

1. Following tanks are necessary for each hotfire:
    a.

Item	QTY	Source
2000 psi K bottle GN2	2	Praxair
6000 psi K bottle GN2	1	Praxair
230L LOx Dewar	1	Praxair
PR-34 Forklift Propane tank	2	Praxair

Packing

1. Ratchet strap GSE 'box'
2. Secure vertical system
3. Secure pressurant tank side
4. Add additional packing material where necessary
5. Ensure Hotfire Packing List is complete

System Preparation

1. Assemble engine (front load aft closure > nozzle > gasket > phenolic liners > gasket > seal disk > injector > forward snap ring)
2. Ensure minimum 6 assembled igniter fixtures
    a. Ensure igniter fixtures are properly assembled
        i. Check continuity of both e-matches: new ematches should have a resistance of ~1 ohm
3. Ensure igniter fixture 1 is attached to burn 1 engine
4. If we have enough igniter fixtures, ensure igniter fixture 2 is attached to burn 2 engine
5. Ensure 11 TC's are attached to burn 1 and burn 2 engine
    a. 5 around injector (4 around, 1 top plate), 2 along length, 4 around nozzle
6. Configure cart 'box' for use with propane
    a. Detach teed off fittings on LN2 line (prechill line)
    b. Attach propane forklift fitting to fuel sides
    c. Attach 5/8" flare to LOx side
    d. Reattach any removed line vents
7. Ensure avionics box cover is secured well
8. Ensure box wire shield is secured well
9. Secure engine mount bearings
10. Secure bolts on blast shield and attach L-brackets
11. Cushion pressurant tank and c channel
12. Attach engine to system
13. Tape over openings

Saturday Night Checkouts

1. Unload system and tools necessary for checkouts to pad
2. Begin propellant move to pad
    a. 2 6K N2
    b. 2 2K N2
    c. 2 propane
    d. 1 LOx dewar
3. Install pressurant side
    a. Bolt in c-channel
    b. Attach high pressure line
4. Remove all packing/transportation material from the system
    a. Cut zip ties holding down RBV's
    b. Cut/remove zip ties/Velcro straps on interfering wires
5. Set up avionics box
    a. 2 AC, 1 Load Cell, 1 TC, 1 PT Board, Cap Fill Comms Board, RTD Board
6. Perform visual inspection of all wiring and sensors and avionics box, report potential issues
    a. esp important: press flow RBV, Igniter/breakwire
7. Perform visual inspection of propulsion system, report potential issues
8. Set up both ground station laptops and connect to cart via secondary ethernet switch

9. Power on cart and visually inspect avionics boards for LED indicators
10. Confirm all boards are connected to ground station computers
    a. 2 E-Reg, 2 AC, 1 Load Cell, 1 TC, 1 PT Board, 2 Cap Fill, RTD Board
11. Ensure burn paramters are correct:
    a. burn duration is correct,
    b. fuel setpoint is correct,
    c. lox setpoint is correct
    d. system mode is 1
12. Perform sensors checkout, note which sensors are broken
    a. LOx Tank PT, Fuel Tank PT, LOx Injector PT, Fuel Injector PT, O-Reg Pressurant PT, F-Reg Pressurant PT
    b. 2 Load cells
    c. 2 Cap fill
    d. RTD
13. Fix broken sensors
14. Perform actuator checkout, note which actuators are broken
    a. Igniter + Igniter Enable Relay
    b. RBV's:
        i. **AC**:
            1. Pressurant Flow, N2 Fill, N2 Vent, Arming Valve, Lox Main, Fuel Main, RQD
        ii. Lox Gems, Fuel Gems
    c. Main valves:
        i. Open Arming Valve
        ii. Open Lox 5 way
        iii. Open Fuel 5 Way
        iv. Ensure main valve actuate all the way open
        v. Close Arming Valve
        vi. Open Main Valve Vent
        vii. Close Main Valve Vent
        viii. Close Lox 5 way
        ix. Close Fuel 5 Way
        x. Open Arming Valve
        xi. Ensure main valves actuate all the way closed
        xii. Close Arming Valve
        xiii. Open Main Valve Vent
        xiv. Close Main Valve Vent
    d. eRegs:
        i. Ensure burn duration is correct, fuel setpoint is correct, lox setpoint is correct, system mode is 1
        ii. Check that quad eRegs are zeroed (closed position, zero encoder reading)
            1. Run **LOx Tank** and **Fuel Tank** eReg diagnostic sequence (diagnostic should open in increments; then static press; then flow for nominal duration)
            2. Send partialOpen(300) and idleClosed (Reset E-Reg) commands to **LOx Tank** eReg
            3. Send partialOpen(300) and idleClosed (Reset E-Reg) commands to **Fuel Tank** eReg
15. Fix broken actuators
16. [PPE: Safety glasses] Perform low pressure leak check of system
    a. Connect 2K bottle to high pressure fill port through regulator (dome pressure line)
    b. Ensure press flow RBV is closed, Ensure E-Regs are closed, Ensure Fill Vent RBV is closed
    c. Open Fill RBV all the way
    d. Slowly increase regulator until high pressure sensor reads ~300 PSI
        i. Confirm pressurant reading matches dome gauge relatively closely
    e. Vent fill line
    f. Wait at least 5 minutes, monitor high pressure sensor to determine if there are any leaks
        i. If necessary, use spray bottle to find leaks
    g. Close vent valve on fill line
    h. Open fuel e-reg to 600 encoder ticks
    i. Open lox e-reg to 600 encoder ticks
    j. Increase regulator back to 300 PSI
    k. Open high pressure flow RBV
    l. Wait for tanks to equalize in pressure
    m. Increase 2K bottle regulator until all three tank pressure are ~300 PSI
    n. Close 2K bottle, vent fill line
    o. Close high pressure flow RBV
    p. Wait 5 minutes, monitor Chronograf to detect leaks
        i. Use spray bottle to find and fix leaks
    q. Open high pressure flow RBV
    r. Open both manual tank vent vents slowly to vent tank pressures
    s. Close all open RBV's
        i. Press Vent
        ii. Press Fill
        iii. Press Flow
        iv. Fuel E-Reg
        v. Lox E-Reg
    t. Close manual tank vents.
17. Check burn parameters
    a. Ensure setpoints
    b. Confirm Flow Mode is set accordingly in dashboard config: Set it in main.jsonc (Hotfire = Mode 1) then restart dashboard
18. **Check continuity of breakwire in ignitor fixture that will be used for burn using multimeter, before and after installation into engine!**
19. Test Aborts
    a. Test manual abort sequence
        i. Begin launch sequence

        ii. Press abort button on dashboard
            1. Confirm Vent Gems open
            2. Confirm both E-Regs don't move
            3. Confirm press flow stays open
            4. Confirm main valves stay open
    b. Test TC abort sequence
        i. Begin launch sequence
        ii. Dip TC in hot water
            1. Confirm main valves close
            2. Confirm Vent Gems open
            3. Confirm both E-Regs close
            4. Confirm press flow closes
    c. Test Load Cell abort sequence
        i. Begin launch sequence
        ii. Step on load cells within 2 secnds
        iii. Step off load cells
            1. Confirm main valves close
            2. Confirm Vent Gems open
            3. Confirm both E-Regs close
            4. Confirm press flow closes
    d. Test Overpressure abort sequence
        i. Set overpressure value to 50 PSI
        ii. Press system
            1. Close fill vent and fill rbv
            2. Close press flow RBV
            3. Close both e-regs
            4. Open fill RBV
            5. Slowly use dome to fill pressurant to 300 PSI
        iii. Begin launch sequence
        iv. Watch for e-reg abort
            1. Confirm main valves stay open
            2. Confirm Vent Gems open
            3. Confirm both E-Regs close
            4. Confirm press flow closes
        v. Vent remaining pressure
            1. Open E-Regs to 600 ticks
            2. Open Press flow RBV
            3. Wait for press tank pressure to return to 0
        vi. Set overpressure value back to 750 PSI
    e. Test begin flow sequence
        i. Igniter abort - With both keys disarmed - should see close RBV's, igniter & 2 way, then abort
        ii. Breakwire abort - With both keys armed and spare e-match, but don't pull apart breakwire connector - should see close RBV's, igniter & 2 way, then breakwire abort
        iii. Nominal startup - With both keys armed and spare e-match, pull apart breakwire connector after e-match goes off - should see close RBV's, Igniter & 2 way, then flow
            1. Time to make sure that burn duration is as expected and system mode is 1
    f. Cover and protect system
    g. Cover and protect GSE 'board'
        i. Wrap essential equipment
        ii. Tape critical ports
20. Power on streaming cameras and ensure streams are visible
21. Power off system
22. Secure GSE 'board' behind I-beam
    a. Ensure all RBVs and lines are secure
23. Ensure GoPro SD cards have enough storage room
24. Ensure GoPros, laptops, UPS, and backup batteries are charging

Ground Station Setup

1. Run cables from control room to I-beam, routing towards the back of I-beam to avoid danger zone
    a. Use 2 spools of Igniter cable
2. Plug in extension cord to outlet & 2 power strips into extension cord
3. Tape power strips onto back of tables
4. Position monitors, connect to power, and connect display cables (display port or HDMI)
5. Plug in and tape down Ground side ethernet switch
6. Plug in ethernet cables to Ground side ethernet switch
7. Connect 300ft ethernet cable to ethernet switch
8. Connect igniter cable to ground station boom box

System Setup **before vertical**

1. Propulsion
    a. Mount blast shield L-brackets and tighten down bolts
    b. Position LOx Dewar and propane tank behind I-Beam
    c. Connect fill lines

        i. Attach 5/8" flare fitting at end of LOx fill line to LOx Dewar
        ii. Attach forklift female fitting to propane tank
    d. Position 6K N2 bottle in GSE 'board'
    e. Position both 2K N2 bottles in GSE 'board'
    f. Position RQD bottle behind I-Beam
    g. Connect N2 Fill RBV to 6k bottle (LEFT HANDED)
    h. Connect pressurant fill line to system
    i. Connect RQD line to system
    j. Connect dome line to LOx Dome port
    k. Open LOx, Fuel manual vents
2. Avionics
    a. Connect ethernet cable coming from Ground Station to GSE 'board'
        i. Ensure that the cable is out of the blast zone
    b. Place pad igniter boom box at end of short jumper from system
        i. Connect to igniter cable coming from Ground Station to GSE 'board'
    c. Route but don't connect power cable to cart, (plug > UPS > cart power strip)

Going Vertical

1. [PPE: Hard hats] Ensure proper tools for securing system are located at pad
2. Attach forklift straps to system cross beam
3. Ensure 4 bolts secure vertical to I-Beam

System Setup **after vertical**

1. **Ensure system is well secured to I-Beam**
2. Install load transfer structure, loads cells and engine
    a. Use burn 1 engine, with attached igniter fixture
3. Install engine electronics
    a. 11 TC's
    b. Igniter
    c. Breakwire
4. Connect system wires to GSE
5. Re-connect LOx, Fuel main valves pneumatic tubes
6. Position GoPro cameras and tripods
7. Position streaming cameras and run Ethernet/Power cables to secondary power strip behind cart
8. Ensure all streaming camera ethernet cables are plugged in
9. Clean off GoPro acrylic cover

System Checkout

1. Two people at the pad, two at the ground station
2. Setup communication between ground and pad
3. Confirm with ground that ground station is ready
    a. Data recording on both computers
    b. Ethernet switch on
    c. Computers plugged in
    d. Flow Mode is set in dashboard config.json
4. Plug in and power on the cart.
5. Confirm nominal data rate from all boards
    a. 2 E-Reg, 2 AC, 1 Load Cell, 1 TC, 1 PT Board, Cap Fill, RTD
6. Ensure burn paramters are correct:
    a. burn duration is correct,
    b. fuel setpoint is correct,
    c. lox setpoint is correct
    d. system mode is 1
7. Sensor checkouts:
    a. Pressure Transducers
        i. Pressurant Tank PT
            1. LOx Tank E-Reg
            2. Fuel Tank E-Reg
        ii. LOx Tank PT
        iii. Fuel Tank PT
        iv. LOx Injector PT
        v. Fuel Injector PT
    b. Fuel Bottom TC, LOx Bottom, Mid, and Top TC's
    c. All 11 engine TC's
    d. Load cells
        i. Using LC0, LC1
    e. RTD
    f. Cap Fill
8. Actuator checkouts (open/close each actuator fully, and confirm with pad)
    a. **Igniter (just continuity)**

        i. Check continuity of igniter wire **WITHOUT** igniter ematches connected
        ii. Connect igniter ematches
        iii. Check continuity **WITH** ematches connected
    b. RQD 2way
    c. Main Valves
        i. Arming valve
        ii. LOX Main
        iii. Fuel Main
        iv. Arm vent
    d. RBV's:
        i. N2 Fill
        ii. N2 Vent
        iii. Pressurant Flow RBV
    e. GEMS
        i. LOx Gems
        ii. Fuel Gems
    f. eRegs:
        i. Ensure burn duration is correct, fuel setpoint is correct, lox setpoint is correct , system mode is 1
        ii. Check that quad eRegs are zeroed (closed position, zero encoder reading)
            1. Run **LOx Tank** and **Fuel Tank** eReg diagnostic sequence (diagnostic should open in increments; then static press; then flow for nominal duration)
            2. Send partialOpen(300) and idleClosed commands to **LOx Tank** eReg
            3. Send partialOpen(300) and idleClosed commands to **Fuel Tank** eReg
9. Test manual abort sequence
    a. Begin launch sequence
    b. Press abort button on dashboard
        i. Confirm Vent Gems open
        ii. Confirm both E-Regs don't move
        iii. Confirm press flow stays open
        iv. Confirm main valves stay open
10. Test begin flow sequence
    a. Igniter abort - With both keys disarmed - should see close RBV's, igniter & 2 way, then abort
    b. Breakwire abort - With both keys armed and spare e-match, but don't pull apart breakwire connector - should see close RBV's, igniter & 2 way, then breakwire abort
    c. Nominal startup - With both keys armed and spare e-match, pull apart breakwire connector after e-match goes off - should see close RBV's, Igniter & 2 way, then flow
        i. Time to make sure that burn duration is as expected
        ii. Watch for Arm/main valves open, ereg open, then all close <burn_duration> seconds later and GEMS open.
11. Cover and protect system
12. Cover and protect GSE 'board'
    a. Wrap essential equipment
    b. Tape critical ports

Sunday Morning Prep

1. Uncover system and GSE 'board'
2. Perform hardware visual inspection
3. Perform avionics visual inspection
    a. Hotfire 7 Avionics Overview - connections for reference
4. Perform engine inspection
    a. 11 TC's well connected
    b. Igniter wire is connected
        i. Both e-matches connected
    c. Breakwire is connected

Procedures Start

Need to create pad team 'packing list' - all items needed at pad (wrenches etc).

Pad Team responsibilities indicated by [M,B,N,O]

1. Confirm injector PTs mapped correctly
2. Confirm flow duration and flow set points are set correctly
3. Confirm abort pressure is set to 700 PSI
4. Confirm burst disks are TAPED
5. **Pad**: Confirm that all line vents are **closed**
    a. **[N,O]** Press Fill Vent
    b. **[N,O]** Propane Vent
    c. **[N,O]** Lox Fill Vent
6. **Pad**: **[M,B]** Confirm that all tank vents are **open**
7. **Pad**: **[M,B]** Confirm visually that main valves are **closed**
8. **Pad**: Confirm **all RBVs** are physically **closed**
    a. **[M,B] BLUE LowP Press Fill RBV, RED HighP Press Fill RBV**
    b. **[O]** Press flow
    c. Zero E-Regs

        i. Fuel E-Reg
        ii. Lox E-Reg
    d. Both gems
        i. **[O]** Fuel gems
        ii. **[N]** Lox gems
9. **Pad**: Confirm **all source tanks** are physically **closed**
    a. **[M]** Fuel Source Tank
    b. **[B]** Lox Dewar
10. Confirm data is being saved to influx
11. Mark on Dashboard that Checkouts are finished
12. Confirm that firmware commit hash is correct:
    a. **[FILL IN COMMIT HASH]**: TC thresholds of 150 & 200, all aborts enabled
    b. **[FILL IN COMMIT HASH]:** TC thresholds of 350 & 400, all aborts enabled
        i. (If changed on 2nd burn, change back to normal thresholds for 3rd burn)

Pressurant Fill [PPE: Safety goggles]

1. Nonessential personnel leave the pad
2. **[N] Confirm RED HighP Press Fill RBV** is connected to **6k bottle**
3. **[N] Confirm BLUE LowP Press Fill RBV** is connected to **6k bottle**
4. **[B]** **Open** pressure builder valves on LOx Dewar (target fill pressures ~100 psi)
5. **[N]** **Open** **2k N2** bottle fully & confirm bottle open with ground station
    a. **Open** **BLUE LowP Press Fill RBV 200ms, 3x 200ms,** and then **8* 50ms increments** until pressure begins to increase
        i. Adjust fill rate to no more than 10 psi/second
        ii. *Confirm Fuel E-Reg High PT AND LOx E-Reg High PT reading*
    b. Fill until bottle levels out
    c. **[N]** **Close** **N2 bottle**
    d. **[N]** **Open** **N2 fill VENT RBV -** low pressure= **3x 200ms,** wait on Pad team to say went to open more
    e. **Close** **BLUE LowP Press Fill RBV, Vent RBV**
6. **Swap to next 2k bottle starting at Step 4**
    a. Continue until final bottle

1. **[Pad Team]** swap bottles:
    a. **[N]** CGA fitting & move **BLUE LowP RBV** to **3k** bottle
    b. **[N]** Confirm **BLUE LowP Press Fill RBV** is **closed**, then **Open** **3k N2** bottle fully & confirm bottle open with ground station
2. Confirm that **N2 Fill Vent RBV** is **closed**
3. **Open** **BLUE LowP Press Fill RBV 200ms, 3x 200ms,** and then **8* 50ms increments** until pressure begins to increase
    a. Adjust fill rate to no more than 10 psi/second
4. Continue fill and monitor pressurant temp sensor until pressure reads 3000 psi - The little chef in ratatouille is called __
5. **Close** **BLUE LowP Press Fill RBV -** do **NOT** vent line if last press, want to keep line pressurized for repress.
6. **[M]** Confirm pad igniter key **disarmed**

Propellant Fill

Propellant Setup [PPE: Cryo gear]

1. **[N,O] Ensure Fuel Fill Line Vent & LOx Fill Line Vent closed**
    a. **[M]** Confirm connectivity of fill lines
2. **[Pad Team]**
    a. **[O]** Confirm that LOx Dewar pressure is >100 psi
    b. **[N]** Confirm 6k N2 bottle is **open**
    c. **[O,N] Ensure LOx Manual Fill Ball Valve & Fuel Manual Fill Ball Valve open**
    d. **[M,B] Ensure LOx Tank Manual Vent** & **Fuel Tank Manual Vent open**
3. (PPE: Hearing protection) All personnel clear the pad, but remain nearby

Fuel Fill

1. **Pad Team**: Confirm that the range is clear, and ready to proceed with fuel fill
    a. If at RFS, ensure halogen lights are off
2. **[M,B] Ensure Fuel Tank Manual Vent open**
3. **Ensure burst disk TAPED and not burst**
4. **[M]** **Open** **Propane source tank** valve fully and slowly.
    a. Make sure pressure is ~10-30psi
    b. Visually and audibly confirm that fuel vent is venting
    c. **Pad Team: [B]** Watch for liquid coming out of vent
    d. **[M]** **Close** Propane Source Tank
    e. **Close propane Tank Vent**
    f. **Disconnect propane fill line**

LOX Fill + Top-off

1. **Pad Team**: Confirm ready to proceed with lox fill
2. **[B]Ensure LOx Tank Manual Vent open**
3. **Ensure burst disk TAPED and not burst**
4. **[O] Open LOx Dewar** valve fully
    a. **[B]** Visually and audibly confirm that LOx tank vent is venting
    b. **Fill until ground station confirms fill mass of _____ total pounds**
    c. **[B,O] Pad Team:** Watch for liquid coming out of vent
    d. **[M] Close** LOx Dewar
5. **Wait for chill in to occur**
    a. **Open LOx Dewar for Top-off**
    b. **Fill until ground station confirms fill mass of _____ total pounds**
    c. **[O] Close Source Tank**
    d. **[B] Close Lox Tank Vent Valve Until Barely Venting**
6. **[O] Open LOX Fill Line Vent,**
7. **[M] Open Fuel Fill Line Vent,**

End Fill

1. **Pad Team:**
    a. **[O] Close** LOx dewar pressure builder
2. Ask for ground station to toggle gems, listen for GEMS cycle:
    a. **[B]** LOx GEMS
    b. **[B]** Fuel GEMS

Fill Line Disconnect

1. **Pad Team:**
    a. **[N]** Disconnect Lox Fill Line
    b. **[B] Fully Close LOx Tank Manual Vent**
    c. **[B] Fully Close Fuel Tank Manual Vent**

Pad Closeout

1. **Pad Team:**
    a. **[M] Ensure both Press Fill RBVs are closed**
    b. **[M] Ensure 6k and 3k** pressurant bottles are **open**
    c. **[M] Ensure** Main Valve bottle is **open**, connected to arming valve
    d. **[M] Ensure** Main Valve regulator is set to 300psi
    e. **[B] Ensure** igniter is properly fixtured in engine
    f. **[B,O]** Remove all ladders from pad
    g. **[N]** Start GoPro recordingsq
2. Begin ESP Cam recording
3. **[M] Ensure** RQD pressure bottle is open all the way
4. **[M] Arm pad igniter key**
5. **[M,B,N,O]** All personnel GTFO (enter bunkers)

Startup

1. Ensure Lox Setpoint is ___ PSI
    a. Burn 1:
    b. Burn 2:
    c. Burn 3:
2. Ensure fuel setpoint is ___ PSI
    a. Burn 1:
    b. Burn 2:
    c. Burn 3:
3. Ensure continuity in igniter, arming valve, main valves, main valve vent, RQD, breakwire
4. **Close LOx Tank Gems** and **Fuel Tank Gems**
5. **Open Pressurant Flow RBV 6x500ms all the way**
    a. Ensure pressure in fuel and lox tanks do not rise
6. **Run eReg Pressurization (both fuel and LOx)** and wait for tank pressures to equilibrate
    a. Ensure Lox Pressure is ___ PSI
        i. Burn 1:
        ii. Burn 2:
        iii. Burn 3:
    b. Ensure fuel Pressure is ___ PSI
        i. Burn 1:
        ii. Burn 2:
        iii. Burn 3:
7. Confirm E-Regs are closed
8. If pressurant tank pressure is <4500 psi, repressurize
    a. **Close Pressurant Flow RBV**
    b. **Close BLUE LowP Press Fill RBV**
    c. **Open RED HighP Press Fill RBV 200 ms** + **3 (100)** ms increments

9. Open **Pressurant Flow RBV slowly 6x500,**
    a. Ensure pressure in fuel, lox, and high pressure tanks do not rise
10. **If Necessary eReg Pressurization (both fuel and LOx)** and wait for tank pressures to equilibrate
    a. Ensure Lox Pressure is ___ PSI
        i. Burn 1:
        ii. Burn 2:
        iii. Burn 3:
    b. Ensure fuel Pressure is ___ PSI
        i. Burn 1:
        ii. Burn 2:
        iii. Burn 3:
11. Once system has been repressurized:
    a. Close all Pressurant Fill RBVS
    b. Open Pressurant Fill Vent
        i. Open 5000 ms (will vent loudly and fast to ensure check valve closes)
    c. Open RQD 2 way and confirm RQD has disconnected
12. Confirm E-Regs are closed
13. Open **Pressurant Flow RBV all the way**
14. Arm dashboard igniter key and **confirm** igniter and breakwire **continuity**
15. Begin countdown!

Recycle

1. Ensure system safety
    a. Depressurize to 20 psi
    b. Ensure adequate time to cool engine
        i. 15 mins or all TC's at 35°C
2. Remove engine (remove blast shield wings if necessary during that process)
3. Reattach propellant and pressurant fill lines, and vent hose to fuel vent
4. Data Analysis
5. Disassemble burn 1 engine to extract parts
6. Camera recycle
    a. Plug in cameras
    b. Replace SD cards
7. Hardware visual inspection
8. Avionics visual inspection
9. Install new engine
    a. TC's
    b. Igniter
    c. Breakwire

System Securing

1. Assess data rates coming from all boards
2. **Close** **Pressurant Flow RBV**
3. **Open** **LOx GEMS** & **Fuel GEMS**
4. **Turn off** dashboard igniter arming key
5. Turn off heater control loops
6. Re-enable propellant tank TC readings
7. Change Dashboard State back to "In Checkout"
8. Go back to top if recycling for another burn
9. Wait for system to be completely vented of LOx and propane
10. Pad personnel close LOx and propane source valves
11. **Open** manual LOx vent valve slowly
12. **Open** manual Fuel vent valve slowly
13. **Open** LOx and Fuel Fill RBV's
14. Carefully disconnect propane fill line (there may be small pressure/liquid release)
15. **Close** **both 3k and 6k** N2 bottles
16. **Open** **both RED HighP and BLUE LowP Press Fill RBVs**
17. **Open** **N2 Fill Vent RBV**
18. If pressurant dump is desired:
    a. Ensure domes are still pressurized
    b. Ensure tank vent RBV's are still open
    c. Open pressurant flow RBV
    d. Confirm system is vented
19. Open both dome valves
20. Stop GoPro recordings
21. Power off cart completely