

# EXPERT SUBSYSTEM BRIEF: HIGH-SPEED TELEMETRY & DUAL-DYNAMIC FAULT MANAGEMENT

**Powerplant Class:** 18,000-Watt (24.1 HP) Twin-Opposed Free-Piston Hydrostatic Engine Set

**Design Authority:** Dr. Patrick Gray

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## 1. HIGH-SPEED, NON-CONTACT TELEMETRY DATA ACQUISITION MATRIX

Because a free-piston architecture lacks a rigid mechanical crankshaft, its stroke length is completely unconstrained by metal links. To allow the engine CPU to manage the fuel injection pacing and valve timing loops, the powerplant requires an ultra-fast, air-gapped position encoder network. This design completely eliminates sliding contact brushes, mechanical wipers, or potentiometer arms, making the tracking grid entirely immune to vibration wear, heat, dirt, oil, or diesel fuel ingress.

- **The Structurally Rigid, Non-Permeable Core:** The central connecting rod linking the combustion piston to the hydraulic pump piston is machined from a solid **3/4-inch diameter Grade 5 Titanium alloy (Ti-6Al-4V)**. Titanium provides an elite structural safety margin against continuous 17,215 lbs stroke loads while remaining completely **non-ferromagnetic (non-permeable)**, making it electromagnetically invisible to the surrounding sensor array.
- **The Permeable Targeting Indicator:** A highly permeable, localized **pure iron clamp/collar** is bolted securely onto the center of the titanium rod. This iron collar acts as the lone magnetic targeting signature for the position grid.
- **High-Density Sensor Runway Construction:** Encircling the moving rod assembly is a stationary structural tube containing a linear array of **64 independent sensor rings** spaced end-to-end to continuously monitor the full 8.00-inch mechanical throw path. Each individual ring consists of a non-magnetic bobbin wound with **60 turns of 30 AWG copper wire** compressed into a tight **1/8-inch active length window**, resulting in an ultra-low-profile, lightweight sensor sleeve.
- **Parallel Analog Front End (AFE) Processing:** Every single one of the 64 copper sensor loops is hardwired to its own dedicated **Texas Instruments high-resolution Inductance-to-Digital Converter AFE (LDC1612 architecture)**. Each local meter continuously monitors its ring at its resonant tank frequency. The microsecond the pure iron clamp passes through a ring, that specific meter's 28-bit registry cache logs a sharp, distinct inductance spike.
- **The 10-Microsecond "Grand Multiplexer" Scanned Sequence:** At the base of the framework sits a high-speed **Grand Multiplexer processing core** equipped with a dedicated CPU, fast static RAM buffer, and non-volatile solid-state storage. To completely bypass serial data bottlenecks, the Grand Multiplexer queries the entire grid using a multi-lane, high-speed **20+ MHz SPI parallel data bus**.

OF NOTE: The Magnetic Based Concept present in this engine design so that the CPU of the Engine can "keep up with" and "monitor" where exactly is the free piston assembly with respect to its distance from Top Dead Center (TDC) or from Bottom Dead Center (BDC) is present in this Engine Design. The system discussed below was originally considered but the form and location of the final Magnetic Sensor system has been changed, so the Magnetic Sensor System discussed below for this engine is no longer the Magnetic Sensor System in this engine design.

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- **Time-Division Telemetry Logic:** Every **0.01 milliseconds (10-microsecond refresh rate)**, the Grand Multiplexer scans the grid. Because every TI meter possesses its own **unique hardware ID number**, the Grand Multiplexer reads the sequenced data string, calculates the exact spatial center of the iron collar via a fast curve-fitting interpolation algorithm, and feeds the engine CPU the absolute distance from TDC and BDC down to the micron.
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## 2. HIGH-ENERGY FAULT MANAGEMENT & OVER-SPEED CONTROL SEQUENCE

An unplanned high-energy error event occurs if a transient hydraulic pressure drop suddenly removes structural pump resistance, or if the fuel system accidentally dumps an over-powered fuel charge, threatening to send the piston violently crashing into the cylinder heads. The engine CPU and structural casing utilize a multi-layered electronic and mechanical defense sequence to catch and kill the runaway stroke:

- **Step 1: 10-Microsecond Kinematic Detection:** As the piston accelerates down the cylinder, the Grand Multiplexer evaluates its velocity vector at 0.004-inch structural increments. If the acceleration delta breaches a strict, pre-programmed safety threshold, the CPU instantly registers a high-energy anomaly mid-beat—well before the piston can even travel an inch.
  - **Step 2: Predictive Mid-Stroke Fuel-Cut:** The CPU immediately triggers an emergency interrupt to the **incremental fuel injection micro-pacing loop**, slamming the high-speed piezoelectric injection valves shut in under 0.20 milliseconds. This immediately cuts off the fuel supply mid-stroke, starves the combustion chamber of new thermal expansion energy, and forces the **19.8-lb sliding tungsten mass** to complete the rest of its travel purely on remaining coasting momentum.
  - **Step 3: The Logarithmic BDC "Boink" Cushion:** Because the fuel was starved within the first 1.05% of active stroke travel, the runaway kinetic profile is drastically reduced. As the assembly reaches Bottom Dead Center (BDC), the piston head bypasses the standard 8.00-inch threshold and encounters heavy, non-linear **rectangular-wire compression die springs** seated inside dedicated over-travel pockets.
  - **Step 4: Safe Absorption & Reset:** The die springs feature an aggressive, logarithmic rate curve that acts as a powerful mechanical brake over a brief 2-inch compression pocket. The springs safely absorb the leftover coasting momentum, prevent a hard metal-on-metal airframe crash, protect the 2205 duplex steel cylinder walls, and smoothly bounce the titanium shaft back into its return cycle to reset the engine within a single beat.
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### 3. LOW-ENERGY FAULT MANAGEMENT & PARTIAL-STROKE RECOVERY SEQUENCE

An unplanned low-energy error event occurs if a cold cylinder, air-charge fluctuation, or fuel delivery drop causes a weak combustion stroke. Without a traditional heavy flywheel to rip the engine through a weak cycle, the **19.8-lb sliding tungsten mass** will hit the high-resistance wall of the 2,721 PSI hydraulic fluid or 20 atm supercharger accumulator, short-stroking and "freezing" the engine mid-beat. To prevent a catastrophic loss of lift during flight, the system deploys an ultra-fast, partial-stroke short-cycle recovery sequence:

- **Step 1: Premature Deceleration Log:** The 10-microsecond Grand Multiplexer grid continuously tracks the piston's speed against a baseline curve. If the titanium rod slows down prematurely or stalls short of its 8.00-inch threshold—for example, getting stuck at the 5.0-inch mark—the CPU detects the stall instantly.
- **Step 2: The High-Pressure Hydraulic Reset Ram:** Rather than executing a slow, time-consuming "full engine redo" (which would drain the lines and stall the flight), the CPU instantly commands a **3-position, center-stop directional valve** to open a path from your **220 cubic inch (3.6 Liter) high-pressure accumulator** directly into the pump face. The high-pressure fluid acts like a hydraulic ram, physically driving the titanium rod assembly backward by **just 2 to 3 inches**.
- **Step 3: Vena Cava Take-Up Absorption:** As the pump face is forced backward to reset the engine, the hydraulic fluid on the opposite side of the internal pump seals is displaced. To prevent this backflow from creating a sudden pressure shockwave that would travel down the return lines and choke the wing motors, the low-pressure return trunk (the vena cava manifold) is integrated with a secondary accumulator pre-charged to a soft **0.5 atmospheres**. This highly compliant reservoir swallows 100% of the backflow pulse instantly, preventing propeller stall and ensuring the four **Parker PGM511-0140 wing motors** soldier right along with nothing more than a minor, brief shaft torque quiver.
- **Step 4: Compressing the Excess Oxygen Cushion:** Because your independent compressor loop always runs a lean-burn profile, the hot cylinder gases already contain an abundant cushion of unreacted, high-pressure oxygen molecules. As the hydraulic reset ram forces the piston backward those 2 to 3 inches, it rapidly re-compresses this trapped oxygen cushion.
- **Step 5: The Microsecond Re-Fire Flash:** Upon verifying optimal re-compression via the unique ID sensor array, the CPU commands an instantaneous secondary fuel injection pulse. The fuel vaporizes instantly in the hot, compressed oxygen cushion, creating an immediate combustion wave mid-stroke. This secondary explosion delivers a massive kick that drives the tungsten mass cleanly past the 2,721 PSI hydraulic threshold, clearing the reservoir and returning the powerplant to a cool, smooth **18,000-Watt cruise loop** within a fraction of a single engine beat.

## 4. PHYSICAL HOUSING & CARGO MATRIX

By implementing these optimized materials, solid-state linear arrays, and low-pressure reservoirs, your twin-opposed powerplant forms a remarkably compact, low-profile package that perfectly preserves the aircraft's transport utility:

- **Powerplant Box Profile:** Placed flat and side-by-side along the interior upper ceiling curve of your 72-inch chord airfoil, the dual modules take up a minimal spatial envelope measuring **18.5" Long × 9.6" Wide × 9.6" High**.
  - **The Cargo Win:** Within your 19.0-inch thick central fuselage shell, mounting the engines along the upper ceiling leaves a massive, unobstructed **9.4 inches of vertical clearance headroom downstairs**. This creates a continuous, wide-open internal cargo tunnel bay measuring **26.4 inches wide × 9.4 inches high**, allowing your 80-lbs combat cargo payload, ammo tins, and medical coolers to slide smoothly into place, completely isolated from the engine's quick recovery loops.
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