Aerosoft F-14A/B

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Primary Flight Systems

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GENERAL

In 1961, the Tactical Fighter Experimental (TFX) program would set design requirements which laid the foundation for the F-14. While the TFX was jointly developed with the US Air Force, the Navy had a distinct desire to merge two previously antagonistic roles into a single airframe. The defensive capabilities of an aerial 'Battleship' first embodied by the ill-fated Douglas F6D Missileer, and the offensive escort & attack capabilities of the F-4 Phantom. The former aircraft benefitted from early detection ability, high payload capacity, and a long loiter time, while the latter depended on speed in relatively close quarter combat. In 1965 General Dynamics' F-111B had won the TFX contract and successfully completed its maiden flight. As a whole, the F-111 was designed for tactical strike first, dogfight second, and carrier operations last. With problems as daunting as an obstructed view of the carrier deck on final approach, it was deemed unsuitable for the Navy. However, the Aardvark served with distinction for 30 years in the former role with the United States Air Force.

General Dynamics had partnered closely with Grumman during the development of the F-111B, and this placed the iconic manufacturer in a strong position when the contract was issued for the Naval Fighter Experimental (VFX) in 1966. Hard lessons had been learned about the TF30's sensitivity to airflow disturbances. More than 6,000 airframe designs of fixed and variable wing geometry were evaluated before landing on design 303E. Swing-wing with afterburning turbofans, the F-14's airframe was designed as a fighter first and a battleship second; (Robert Kress, Grumman) *"We were totally preoccupied with producing a fighter, with a basic weapon fit of four AIM-7's and two AIM-9's. Then we sat back and figured out how to screw six AIM-54's onto it without messing up the fighter role."*

In addition to early requirements, intense pressure was brought on American designers in light of the stunning high altitude performance of the MiG-25 Foxbat and low altitude threat of cruise missiles. The counter to both of these concerns was AIM-54/AWG-9 combination. Phoenix was an evolution of the AAM-N-10 Eagle developed by the Bendix Corporation for the Missileer in the 1950's. Hugely valuable research and technology were transferred to Hughes, the same company who designed the high powered pulse-Doppler AWG-9. It was a decided advantage to have only one command and control system capable of launching & guiding the AIM-54, and to have both designed by a single contractor. Many tests, some spectacular, validated the combination.

- Launched from 41,000ft at M1.2, an AIM-54 destroys a drone flying 72,000ft at M2.8
- Launched from 44,000ft at M1.5, an AIM-54 destroys a drone at an initial range of 110nm
- Launched from 10,000ft at M0.72, an AIM-54 destroys a drone 50ft above the waves at 22nm
- Six AIM-54's launched sequentially in a 38s period destroyed four drones; one miss and one 'no-test'.

In the spring of 1982, evaluation of the F-14 completed and Commander John Wilson presented his findings:

"The F-14A is the most Formidable and versatile weapons system flying today. There are aircraft that fly faster or slower, but not both. Some fly higher, turn tighter, are better in the one-on-one visual ACM area, but there is none, repeat none, that compares across the entire spectrum of fighter roles and missions, and none that can track 24 targets and selectively engage six targets simultaneously in the all-weather environment. It is the Phoenix/AWG-9 that really makes the F-14 unique among fighter aircraft."

At the turn of the 20th century, the intended impact of the Wright Brothers' marvelous new creation had been a deterrent of war. With the advantage of aerial reconnaissance, flanking maneuvers by ground troops could be easily seen and countered, forcing all advances to be frontal attacks....who would engage in such madness? Perhaps the greatest testament to the Tomcat's efficacy is the absence of violent encounters. If any doubt lingers about the potency of Tom's cat, ask any Naval aviator what happened when the beam of an AWG-9 focused on the signature of an Iraqi MiG.

FLIGHT CONTROLS

The A model and early B model Tomcats were 4th generation combat aircraft. Almost all control inputs from the pilot are directly fed into the flight hydraulic system, which powers the control surfaces. The only exception are the wing spoilers, which are powered by an electro-hydraulic system that applies a profile based on the aircraft's configuration (see Lift Augmentation - Spoilers). Trim input is provided by a spring which physically offsets the control stick.

LONGITUDINAL CONTROL

Pitch authority is given by symmetric deflection of the horizontal stabilizers. In normal flight, positive limit is 30° pitch up and lower limit is 10° pitch down.

LATERAL CONTROL

Roll authority is given through two sets of control surfaces; asymmetric deflection of the horizontal stabilizers and asymmetric deflection of the wing mounted spoilers. Horizontal stabilizers can be moved ±7° relative deflection, while each spoiler can be deflected up to 55°. However, spoilers are only active at wing sweep angles less than 57°.

Above 15° Units AoA, lateral control response decreases significantly and becomes ineffective for combat maneuvers. Consequently, rudder input is used for both primary lateral and directional control input during aggressive combat maneuvers. This can be particularly hard on the TF30's; controlled and precise inputs are needed to prevent compressor stalls.

DIRECTIONAL CONTROL

Yaw authority is given through rudders on the two vertical stabilizers.; Maximum deflection is ±30° at low speeds. Above 250KIAS, control authority decreases linearly until 400KIAS, where the deflection limit is ±9.5°

AIRFRAME STABILITY

In normal flight conditions the F-14 exhibits good stability about all axes, and trimmed flight should not be difficult to achieve. However, there are three characteristic stability issues of which pilot's should be aware.

Wing Rock: During carrier launches, the high pitch and alpha rate result in a low roll stability. Early model Tomcat's in particular will frequently roll uncommanded and require pilot correction.

Dutch Roll: Directional stability decreases almost linearly above 15 Units AoA and goes negative above 22 Units AoA. Low directional stability combined with strong dihedral effects (yaw induced roll) and adverse yaw (roll induced yaw) make the Tomcat susceptible to a coupled oscillation known as Dutch Roll (DR). At approach AoA, the Tomcat's airframe has a neutral stability to DR oscillations and a negative stability at higher AoA. Neutral stability means that a existing DR will continue indefinitely without corrective input, while negative stability means the DR will be divergent and eventually lead to departed flight. It's critical for the pilot to understand that corrective rudder input needs to be given pre-emptively to dampen out a DR oscillation. While not a hard and fast rule, a good starting point to dampen out a DR is to give rudder input opposite of the return yaw movement. (i.e. when the nose is moving towards centre, give a light input away from centre).

Departed Flight/Flat Spin: As Angle of attack increases, both roll and yaw damping decrease. These can combine with a negative yaw stability to generate strong uncommanded yawing moments during maneuvers.

Even more difficult is that yaw movement is typically masked by roll, and difficult to detect from the pilot's seat. With wings swept forward this can develop into a flat spin, a single engine compressor stall will greatly exacerbate the problem. Landings are or particular concern since departed flight during any stage of approach will surely result in loss of aircraft.

There is no official recovery method for a fully developed flat spin and for many years it was thought to be an irrecoverable condition. However, a method pioneered by Joe "Hoser" Satrapa (for whom the method is named) can recover aircraft if initiated above 10,000ft AGL. With flaps up and wings swept aft, the Center of Lift shifts aft and this creates strong nose down moment that pulls the F-14 out of a fully developed spin.

AUTOMATED FLIGHT CONTROL SYSTEM (AFCS)

STABILITY AUGMENTATION SYSTEM (SAS)

The Stability Augmentation System makes the Tomcat a less responsive aircraft by reducing pilot control input. This is accomplished in two ways; (a) the maximum deflection limit is reduced for all three control axes, and (b) the maximum control surface deflection rate is reduced.

E.G. In normal flight mode, the rudders can be displaced at 106°/sec, with a maximum deflection of 30°. With the Yaw SAS channel engaged, control deflection rate is limited to 80°/sec, giving a maximum control response of 19° which can be achieved in 0.24s (compared to 0.18s at 106°/sec).

It is critical to understand that the SAS system provides a passive stability by reducing the pilot input; it will not correct under-damped movement or substitute for coordinated control inputs. Since the SAS effect is passive and inhibitory, the Roll SAS channel is frequently turned off during combat maneuvers.

AILERON-RUDDER INTERCONNECT(ARI)

The early model F-14's were notoriously difficult to land on an aircraft carrier, controlling the nose has been described as trying to herding an elephant. To help improve stability, engineers as NASA Langley developed a control system to improve coordination between the lateral and directional axis. In the current release an ARI has been implemented that is heavily based on Control System C, as described in NASA-TM-81833. The ARI is identical feedback/response in the landing configuration, the only changes were small reductions in two gain values with the landing gear up to better integrate with normal flight and air combat maneuvering.

The ARI is installed on the Block 110 A model and on all B model F-14's. The system is integrated with the SAS, and is engaged or disengaged depending on the position of the SAS switches. Benefits of the ARI are an improved stability during approach, and a stronger resistance to departed flight and spin entry. The ARI is most active at slow speeds and high angle of attack, and gains a boost when the landing gear is deployed. As airspeed increases above M0.55, the ARI input begins to taper minimumal input above M0.65.

AUTO PILOT

The autopilot system has four modes of operation based on the position of four toggle switches and the activation of the sub modes. <u>All armed functions of the autopilot are engaged by pressing the Nose Wheel Steering button, which is assigned to Tailwheel Lock [Shift+G] in FSX.</u>

(1) Control Stick Steering mode that operates in Pitch and Bank hold. This is the default mode that is activated when the Autopilot Master switch turned ON, or when any of the AP sub-modes are selected but inactive.

(2) Altitude hold has a two-step arm & engage procedure.

(3) Heading hold has a passive arm & engage procedure. Altitude hold and Heading hold can be used simultaneously or independently (i.e. you can operate in Altitude Hold mode while also operating Bank Hold in Control Stick Steering).

(4a) Vector mode has a two-step arm & engage procedure. It will follow a loaded flight plan either in either Pitch CSS or Alt Hold depending on the option selected in the Control Tab of Aircraft manager.

(4b) Automated Carrier Landing System (ACLS) has a four-step arm & engage procedure. ACLS controls both the longitudinal and lateral control surfaces, and can be combined with the Approach Autothrottle for a hands free carrier landing. The AFCS Emergency Disengage paddle is assigned to Toggle Jetway [Ctrl+J], and will set all autopilot switches to OFF.

Control Stick Steering (CSS) is the default Autopilot mode and holds pitch attitude and bank angle. CSS is active in three different conditions. (A) When the AP master switch is turned on and no other AP switches are turned on. (B) When the Alt Hold, HDG Hold, VEC, or ACLS modes are armed but not engaged. (C) As the fallback control mode when Alt Hold, HDG Hold, and VEC are armed but not engaged.

In the real world F-14, CSS is based on force input rather than displacement of the control stick. To replicate this as well as possible in FSX, only the first 15% of joystick input will register as valid input. Above 15%, input saturates and there will be no increase in the AFCS response. It is significantly easier to control the aircraft in CSS by using discrete control inputs (i.e. pitch input only, then bank input once pitch input has stabilized). Cross axis input and unanticipated motion can quickly exceed the limited authority of the AFCS.

Altitude Hold is armed when the ALT Hold toggle switch is on. While armed, the AFCS operates in CSS Pitch Hold mode. Once at the desired altitude, press the Nose Wheel Steering (NWS) button and center the stick. Longitudinal input of more than 5% will disengage Alt Hold and revert to Pitch Hold (no switches move). Pressing the NWS button again will re-engage Alt Hold. As with CSS, the AFCS has limited authority over the control surfaces, so vertical speed should be close to zero when the target altitude is selected. Engaging Alt Hold when not in level flight can result in large oscillations with long seek times.

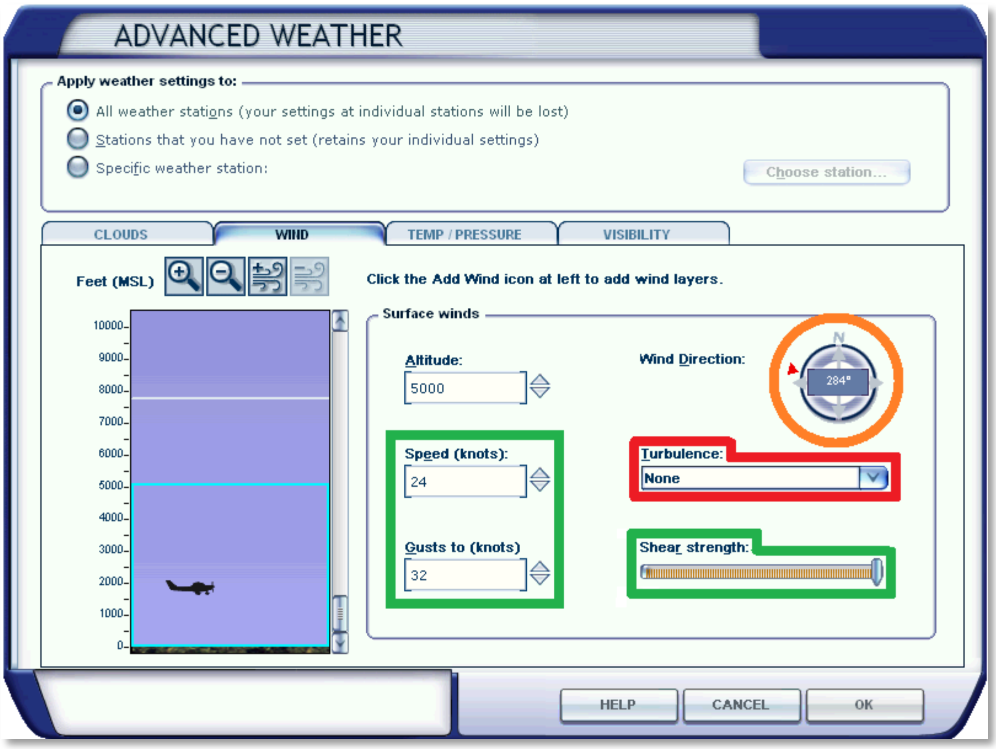
Heading Hold is armed when the HDG Hold toggle switch is on. While armed, the AFCS operates in CSS Bank Hold mode. Once at desired heading, decrease bank angle to less than +/-5 deg and center the control stick; HDG Hold will acquire and hold the current heading. Lateral stick movement of more than 5% will disengage HDG Hold and revert to Bank Hold (no switches move) in an armed state.

Vector mode follows a loaded flight plan created either in FSX or by 3rd party software. Moving the VEC/ACLS toggle switch to VEC with AP ON arms path follow for a loaded flight plan, but maintains Bank Hold mode. Pressing the NWS button will engage the autopilot to follow the loaded flight plan. Lateral stick movement of more than 5% or repressing the NWS button will disengage VEC path follow and revert to Bank Hold.

***There is an option in the Controls tab of the Aircraft manager to enable VEC mode to follow the ALT profile of a loaded flight plan. Flight plans do not normally contain good altitude data, so this option is recommended for users who have 3rd part flight planning software.*

ACLS combines with the approach auto throttle to perform a hands free carrier landing. Moving the VEC/ACLS switch to ACLS arms the mode, and once alignment is complete, engaged by pressing the NWS button. ACLS is disengaged by re-pressing the NWS button or with Lateral/Longitudinal control stick input. <u>When ACLS is disengaged, all AP switches are set to OFF</u> and aircraft control is returned to direct pilot input.

ACLS SETUP



As with most AFCS functions, the ACLS has limited control authority. Several factors are critical to successful use. Winds are acceptable (and maybe even desirable!), but they must be steady and aligned with the carrier deck. Gusts, turbulence, and off direction winds can easily exceed the corrective authority of the ACLS and knock the aircraft irrecoverably off course. Second, the initial alignment must be solid; this means a small and stable glide slope deviation. If ACLS is engaged while passing through the target region it cannot be depended on to acquire the Glide Slope in a quick and accurate manner. The following weather conditions should be observed when attempting an ACLS landing:

- Wind Speed - This is not an overly sensitive variable. The ACLS has been tested with windspeeds up to 24 knots with gusts to 32 knots. Gusts are more problematic than peak wind speed.
- Wind Shear - All shear levels were tested and have little impact on performance.
- Wind Direction - Wind direction should be aligned with the carrier heading, and this is authentic to normal carrier operations. If the error is too large, red text will pop up in the ACLS Window stating that the wind direction needs to be adjusted (and will give the required heading).
- Turbulence - **Should be set to none**. Because of the limited control authority of the ACLS system combined with implementation of wind turbulence in FSX, the ACLS was knocked irrecoverable off course in most instances during testing.

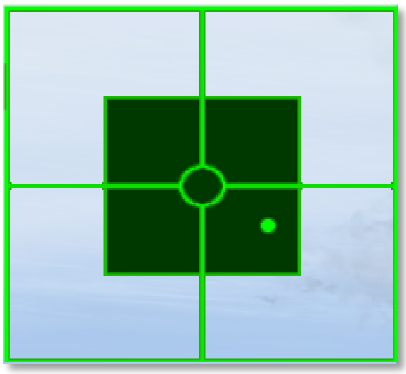
Do not expect to TRAP every attempt with the ALCS, the control system was designed around realistic parameters with plausible limitations. Following the recommended weather settings will ensure the ACLS control system is not overwhelmed and that the F-14 is not blown completely off approach; as conditions approach maximum recommended, it will be more likely that pilot intervention will be necessary. Pre-set carrier flights that come packaged with the F-14 have a broad range of weather scenarios which meet the above criteria.

ACLS IN THE SIMULATION

This first step in a successful landing is aligning the ALCS system. In real life, alignment is a closely coordinated effort between the Pilot, RIO, and Carrier Control. Because the simulation lacks adequate verbal feedback, we've implemented a visual alignment system to augment situational awareness (next page).

The Pilot's standard information display for ACLS alignment is found on the left side of the VDI.

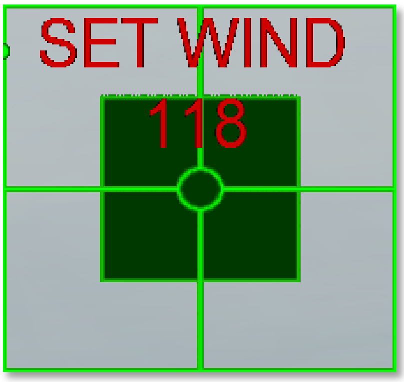
- **Initial** - When in range of the carrier, **LANDING CHK** should be illuminated. If not, and if **VOICE** is illuminated, then it means the carrier is not suitable for an ACLS landing. The two possible reasons for **VOICE** being illuminated are either a carrier which is not compatible with the F-14, or the wind direction is not aligned with the carrier heading (see alignment gauge). If neither LANDING CHK or VOICE are illuminated, then the F-14 is not set to the carrier's TACAN channel.
- **Configure -** When the ACLS/VEC switch is set to ACLS, **A/P REF** will illuminate. This true whether the AP master switch is ON or OFF.
- **Alignment -** **ACL READY** will illuminate when the F-14 is on glide slope with an acceptable deviation and the ACLS/VEC switch is set to ACLS, even if AP Master is set to OFF. **A/P CPLR** will illuminate when the AP Master is ON and the carrier is ready to take control of the aircraft.
- **Final -** When **A/P CPLR** is illuminated, pressing the NWS steering button will transfer control of the aircraft to the carrier. When this happens, **CMD CONTROL** will illuminate and **A/P REF** will extinguis. **10 SECONDS** will illuminate when the aircraft is less than ten seconds from the carrier on final approach.



In addition to the Pilot's display, we have also created a 2D gauge to assist with visual alignment, and you can choose to activate or deactivate the gauge from the Controls tab of the Aircraft Manager. When active, the gauge is tied to the ACLS/VEC switch and will display whether or not the Autopilot is engaged. In real world operations, the ACLS system was also used during manual approaches because of its high level of positional accuracy and feedback.

The target for ACLS alignment and engagement is the dark green box, while the center circle is the target for an OK approach rating.

Aside from orientation, an important feature of the alignment gauge is weather setup. In order for the ACLS system to become active, the carrier must be steaming directly into the wind. The alignment gauge takes out guesswork and tells you exactly what the wind direction needs to be.



If **SET WIND XXX** appears, then simply adjust the wind direction in either the basic or advanced weather options. If no text appears, then wind direct is set!

Below is a quick procedure which can help in early attempts. Note that the alignment gauge can be used any time the VEC/ACLS switch is set to ACLS.

1. Start with mild weather and low wind gusts
2. Setup 5-10nm outside of the carrier
3. Make sure you are tuned to the carrier's TACAN channel, the USS Kitty Hawk is 112.10
4. Set the STEER CMD mode to AWL/PCL to show the ILS needles
5. Airspeed 250-300KIAS, Hook Down, Manual flight mode, All SAS channels ON.
6. Arm ACLS [CRTL+A]
7. Check initial position and direct aircraft until the dot is moving in the outer region of the gauge
8. Deploy the Speed Brakes and drop the Gear, continue moving towards gauge center
9. Flaps down at 180-200KIAS
10. Engage Auto-Throttle [Shift+R] around 12 units AoA
11. Engage Auto Pilot [z] with pitch hold set between 6-9degs
    - ⇨ If you have trouble here, make sure AoA is stable and pitch input is near center (trimmed flight)
12. Engage ACLS by pressing the NWS button [Shift+G] when dot is stable inside the solid green square.
13. Watch the oscillations in the flight path and see how they recover naturally. The ACLS system has three to four compound control systems per axis and will not fly like it's on a set of rails.

A good idea for a first ACLS landing is attempt is to use the SparrowHawk HUD (press [H] if in an A model Tomcat) and also the MiniHUD [Shift+1]

POWER PLANTS

TF30-PW-414A: The Pratt and Whitney TF30 was the world's first afterburning turbofan, with design beginning in 1958. Turbofans have two decided advantages over turbojets. Using excess power accumulated from the core turbine, uncombusted air is pushed around the engine and directly into the exhaust. This provides an increase in fuel economy in dry thrust mode, and an increase in exhaust oxygen content which generates greater afterburning thrust. First fitted on the General Dynamics F-111, a substantial problem emerged in the form of compressor stalls. This directly influenced the design of the F-14 (and combat fighters to follow), giving a wide spacing to the engine nacelles. This allowed straight inlets with minimal disturbance from airflow around the fuselage.

While many of the problems seen with the F-111 were fixed, a new phenomenon emerged; fuselage lift. Traditional fuselage and wing platform combinations experience a sharp decrease in lift at the onset of stall. However, the large flat surfaces on the F-14's fuselage increase lifting force even after the main wings have stalled, with a peak airframe lift generated around 30 deg AoA. During hard vertical manoeuvres, AoA can be pushed passed 40 deg. The outstanding aerodynamics of the F-14 meant that pilot's frequently had to throttle *back* during pursuit, decreasing and disrupting airflow to the engines. These factors far exceeded anticipated stress on the engines, and led to a series of accidents in which not just machine, but lives were lost.

For all its shortcomings, the TF30 was chosen because at the onset of production it was the only proven engine of its class. Compared to its turbojet counterparts, the TF30 boasted significant gains in augmented thrust, particularly in the supersonic region. The F-4’s J79 turbojet and the F-14's TF30 are both engines in the 12,000lb dry thrust class. While the J79 experiences an increase in thrust of 5,940lb between MIL and MAX augmentation, the TF30 gains 8,550lb. The only other competitor at the time was the F401 (described below).

F110-GE-400: The General Electric F110 is the final product of a joint venture by the Navy and Air Force, originally called the Advanced Technology Engine or ATE. Designated the F401 (but closely related to the Air Force's F100), it made its first flight in the Tomcat in September 1973. Just seven months later in April 1974, the project was shelved after it was decided that improvements were needed and cost overruns of the F-14 program as a whole were elevating congressional blood pressures. A second joint venture by the Navy/Air Force resumed development again in 1979 to act as a fall back for the TF30 and F100 (respectively). Under the title 'F110', the first flight test took place in 1981. Justifiably painted as the Super Tomcat, the B model F-14 finally had a thrust to weight ratio greater than unity when in a dogfighting configuration at medium fuel capacity. The F-14B's flight tests boasted a 32% increase in cruise time on station and a 62% increase in combat radius for deck launch intercepts.

Several other decided benefits made their way into fleet operations. Catapult launches could be performed at MIL thrust, improving fuel consumption, safety, and visibility in night missions. The TF30’s augmentation cones could be seen up to 10 miles away and compressor stalls during catapults invariably led to the loss of an aircraft. A moderate drawback of the F110 was that aerial restarts of a stalled engine required an airspeed of 450KIAS, but this was largely offset by the substantial increase in engine reliability. A minimum pressure ratio of 3.0 ensured strong compressor stall resistance across all thrust conditions and removed restrictions on throttle movements during combat manoeuvres. The F110 became the engine which matched the airframe, and allowed the Tomcat to be flown at its greatest potential.

ENGINE FAILURES

Compressor Stalls

All stall and recovery logic is randomized. Correctly following emergency procedures will only increase the chance of recovery, and is not a guarantee of success. It is strongly suggested that the MiniHud be used to gain an understanding of the stall response and recovery.

Compressor Stalls (*TF30 Only*):

- **Maneuver Induced:** In order of importance; increasing Sideslip (beta) angle, Angle of Attack, and Altitude will stress the turbines and increase the chance of a compressor stall. This becomes particularly tricky at higher Angles of Attack, when roll is primarily controlled by rudder input.
- **Supersonic Deceleration**: At speeds above M1.4, minimum throttle setting is MIL thrust.
- **Idle Thrust**: At engine speeds below 80% RPM, the turbine becomes sensitive to rapid throttle changes, and care should be taken to make slow adjustments.
- **Mach Lever:** During subsonic flight at AoA greater than 17 units, the Mach Lever system will override pilot input and maintain a minimum engine speed of 80% RPM to improve compressor reliability.

Compressor Stalls (*TF30 and F110*):

- **Hot-start**: Hot-starts occur if fuel is introduced before Ng (Gas-producer RPM) has reached 18%. The combustion chambers gets flooded with fuel with insufficient airflow. You will see that TIT temperature gets very hot.
- **Inlet Ramps, Catapult launch**: Catapult launches should always be performed with the inlet ramps in 'Auto'. When in 'Stowed' mode, the surge of hydraulic pressure during cat launch can drive the inlet ramps out of their stow locks and congest the air intake. A compressor stall will quickly follow with little altitude or speed to recovery. Expect a soggy sailor.
- **Inlet Ramps, Supersonic Acceleration**: Airflow into the gas turbine must be slowed to subsonic speeds to prevent normal shock from occurring in or near the intake.

STARTING SYSTEM

The starting system for each engine combines a starter/generator, start switch and starter relays. Fuel is controlled by the throttles, which should start in the 'OFF' position. With Ground Power connected or the Emergency Generator active, the starter motor will rotate the gas generator turbine. When it reaches sufficient 18% RPM, the throttles can be moved to 'IDLE' and the engine will light-up. The starter switch will automatically return to center when an engine reaches 45% rpm.

START SWITCH

A three position start switch is located on the left console. The can be set to LEFT or RIGHT position to energize the left and right engine starter systems.

ENGINE INSTRUMENTS

ENGINE RPM

Power by the Essential AC No.2 Bus, this gauge indicates the turbine compressor speed in percent of maximum revolutions per minute. Typical idle values are 63-74% and typical MIL trust values are 99-100%.

ENGINE TEMPERATURE (TIT)

Power by the Essential AC No.2 Bus, Engine temperature indicates the temperature in the combustion chamber. Normal operating range is 600-1200°C.

FUEL FLOW

See Fuel System section.

OIL PRESSURE / OIL TEMPERATURES

See Oil System section.

ENGINE EXHAUST NOZZLES

ALL ENGINES

One of the characteristic sights of a parked Tomcat are asymmetrically opened exhausted nozzles. The starboard (right) engine is shut down first, is electrically held in place while electric power remains. During the port engine shutdown sequence, the hydraulic systems take longer to go offline than the generators and causes the nozzle to be stuck open.

TF30-P-414A

- With Weight on Wheels and throttles at idle the nozzles are fully open to reduce thrust
- During all other MIL thrust or less settings the nozzles are fully closed
- Nozzles increase area linearly from Thrust Augmentation Stage 1 to 5.

F110-GE-400

- With Weight on Wheels and throttles at idle the nozzles are fully open to reduce thrust
- With Weight <u>off</u> Wheels, gear down, and throttles at idle the nozzles are open 26% or less
- With gear up and throttle at idle, the nozzle position ranges from 20-100% depending on speed and altitude
- At MIL thrust, nozzle position is 3%-10% depending on speed and altitude
- At Stage 1 Augmentation, nozzle position is 5-12%
- Normal position during Stage 6 Thrust Augmentation is 60-70%, but can be as high as 90%

LIFT AUGMENTATION

WING SWEEP

During normal operation, the Tomcat's wings can sweep from an AFT position of 68° to a forward position of 20°. Sweep control is implemented through hydro-mechanical screwjack actuators. Input can be received from the Central Air Data Computer (CADC) or by direct pilot input. Regardless of the input method, several limitations exist:

- Maximum sweep rate is approximately 15°/sec
- During High-G maneuvers, sweep rate will decrease and stop at G loads less than -1.0 or greater than +5.0g.
- If Auxiliary (inboard) Flaps are deployed, interlocks prevent the wings from being swept aft of 21°
- If Primary (outboard) Flaps are deployed, interlocks prevent the wings from being swept aft of 50°

Within these limitations, four modes of sweep input are possible

AUTO MODE (CADC)

- Sweep Ch.1 applies a mach based profile for altitudes less than 14,000ft
- Sweep Ch.2 applies a mach based profile for altitudes greater than 20,000ft
- Between 14-20,000ft, Ch.1&2 are interpolated to find the optimum sweep angle
- Automatically resets failures if RPM drops below 30% N1

BOMB MODE (CADC)

- When in Bomb Mode, 'MAN' flag appears on the sweep indicator
- At lower mach numbers, the wing sweep is set to 55°
- If the Auto Mode calculated sweep angle for the current flight mach number and altitude is greater than 55°, then Auto Mode sweep logic will be set.
- At all altitudes, flight Mach Numbers greater than 0.35 will cause the glove vanes to extent

MANUAL MODE (CADC)

- When in Auto Mode or Bomb Mode, pressing AFT on the wingsweep rocker will enter Manual Mode
- When in Bomb Mode, pressing FWD or AFT on the wingsweep rocker will enter Manual Mode
- If the sweep angle calculated in Auto Mode intercepts the command angle in Manual Mode, then sweep mode will revert to Auto. This can happen in two ways:
    - If wings are swept forward to the angle command by Auto Mode
    - If the wings are held at a fixed angle, and airspeed increases such that angle command by Auto Mode decreases and intercepts the fixed angle.

EMERGENCY MODE (PILOT)

- To engage emergency mode, raise the Emergency Wingsweep cover
- At lower mach numbers, the wing sweep lever is held in place with spider detents in 4° increments
- With Weight on Wheels, Oversweep can be entered and wings can be swept aft to 75°
- Emergency mode can only be exited with wings swept forward to 20°. (This is to prevent accidents on a crowded deck)

FLAPS & SLATS

Each wing has three lift adding devices; leading edge slats, outboard trailing edge flaps, and inboard trailing edge flaps. All are powered by the combined hydraulic system. There are two separate mode of input which should not be mixed; Flap Lever (Primary Flaps) and Flight Stick (Maneuver Flaps)

- Leading Edge Slats can be deflected up to 17° from Flap lever input and 7° with maneuver flap input
- Outboard flaps can be deflected up to 35° from Flap lever input and 10° with maneuver flap input
- Inboard flaps are deflected 35° from Flap lever input only
- Mechanical locks prevent the Flaps and Slats from extending at sweep angles greater than 50°
- Inboard Flaps will Automatically retract with a loss of electrical power

FLAP LEVER INPUT

- Typically only two positions are used, UP and DOWN.
- Once the Flap lever is extended past 5°, Inboard flaps will fully extend to 35°
- Flaps will automatically retract at speeds above 225KIAS
- Flap lever input should not be given with Maneuver flaps extended, because the rapid change in direction can damage the flap motor. This can be avoided by always extending the landing gear first.

MANEUVER FLAP INPUT

- Maneuver Flaps can be command both automatically and by the pilot
- Maneuver Flaps cannot be extended at mach numbers greater than 0.9.
- If sweep angle is greater than 25°, then glove vanes will also extend
- (Pilot) Using flight stick input, pilot's can extend or retract the maneuver flaps as desired. In FSX this input has been assigned to *Floats (extend)*; repeated button presses will both extend and retract.
- (Auto) Maneuver flaps cannot be extended with gear down. Maneuver flaps will retract if they are active when gear is extended.
- (Auto) If Angle of Attack exceeds ~10.5 Units, then maneuver flaps will be extended and override pilot input.
- (Auto) If Angle of Attack falls below ~7.5 Units, then automatically extended maneuver flaps will retract.

SPOILERS

Each wing has a set of inboard and output spoilers which are powered by the combined hydraulic system. There are four modes of spoiler defection.

- Spoilers are fully retracted at sweep angles greater than 57°
- Symmetrical (SYM) deflection of the spoilers is used to adjust the lift and drag configuration
- Asymmetrical (ASYM) deflection of the spoilers is used to augment roll effectiveness
- Direct Lift Control (DLC) is used to adjust Angle of Attack on approach. In FSX pilot input has been assigned to *Floats (retract)* ; repeated button presses will both extend and retract.
    - The purpose of DLC can be derived from its name, as the primary effect is to reduce the lift produced by the wings and which causes a quick decrease in the Angle of Attack for the same airspeed. Some drag is added, but this effect is of secondary importance.

- Naval Aviators fly approach based on AoA. If speed is a little high, then DLC will immediately increase AoA and slowly decrease airspeed.
- Is designed to be toggled on and off. Can be useful to turn on during level (banked) flight, and turn off during turns when greater lift is needed.

- Ground Roll Aero Braking is armed with or without wheel antiskid via three position switch. When armed, it will automatically deploy with weight on wheels and throttles retarded to idle.

FLAPS UP - ALL SPOILERS

- No deflection from 0 to ±1" stick deflection
- (ASYM) deflection from 0° to 55° over 1" to 3.5" stick deflection

FLAPS DOWN / DLC STOWED - ALL SPOILERS

- (SYM) -4.5° deflection from 0" to ±0.5" stick deflection
- (ASYM) deflection from -4.5° to 10° over 0.5" to 1.5" stick deflection
- (ASYM) deflection from 10° to 55° over 1.5" to 2.5" stick deflection
- (ASYM) 55° deflection from 2.5" to 3.5" stick deflection

FLAPS DOWN / DLC ENGAGED (NEUTRAL)

- Outboard Spoilers: Identical to FLAPS DOWN / DLC STOWED
- Inboard spoilers
  - (SYM) 17.5° deflection from 0" to ±0.5" stick deflection
  - (ASYM) deflection from 17.5° to 22° over 0.5" to 1.5" stick deflection
  - (ASYM) deflection from 22° to 55° over 1.5" to 2.0" stick deflection
  - (ASYM) deflection from 2.0" to 3.5" stick deflection

GROUN ROLL AEROBRAKE - ALL SPOILERS

- (SYM) deflection to 55°

GLOVE VANES

At the leading edge of each wing root is a pair of retractable canards referred to as Glove Vanes. Their pitch position is static, which means they provide as passive effect by increasing the total lifting area. In the supersonic regime the Glove Vanes were used in an attempt to destabilize the Tomcat's heavily damped pitch response. Marginally effective, the glove vanes were deleted in later A model Tomcats, and occasionally welded shut in the field.

- Automatically extend with maneuver flaps at sweep angles greater than 25°
- Automatically extend in Bomb Mode for mach numbers greater than 0.35
- Automatically extend at mach numbers greater than 1.5

SPEED BRAKES

The Tomcat's speed brake lies in the center of the empennage, between the two vertical stabilizers. Upper and lower surfaces can deflect up to 60° to increase drag while having virtually no effect on lift.

- Extension is always pilot controlled
- Automatically retract at MIL thrust
- Will blow shut as speeds greater than 400KIAS
- In both of the above, a partially (or fully) closed speed brake will not return to its original position.

AIRCRAFT FUEL SYSTEM

- Forward fuselage, Right fuselage, and Right Wing tanks feed to the Right engine
- Aft fuselage, Left fuselage, and Left Wing tanks feed to the Left Engine
- Fuel is delivered through engine driven motive fuel pump (independent of electrical power)
- BINGO fuel set weight is adjustable and found on the fuel instrument panel
- QTY SEL switch is spring loaded to display Feed Tank quantity, and must be held to display either Wing or External quantity
- Feed Tank Group = Sump Tank + Box Beam Tank
- Each Box tank holds 1,300lbs (6.7lb/Gal) of fuel and is fed directly from Fuselage, Wing, and External Tanks.
- If Box tank is full, then fuel is dumped into fuselage tanks
- Each Sump tank hold 300lbs of fuel of fuel
- Sump tanks are connected to (1) Box Tanks, (2) Fuselage Tanks, and (3) Opposing Sump tank
    - (1) Is mode of operation if (a) FEED set to NORM (b) fuel in box tank and (c) dry thrust
    - (2) Is mode of operation if (a) FEED set to NORM (b) fuel in fuselage tank and (c) wet thrust
        - It is normal for the feed group quantity to drop to 1,200lbs during AB operation
    - (3) Is mode of operation if (a) FEED set to NORM (b) no fuel in fuselage tank and (c) dry thrust
- The connection with the highest
- During negative G maneuver (<0.0g's), fuel stops flowing into sump tank
- A sustained negative g maneuver will eventually starve engines
- If motive fuel pump fails, then Afterburner is limited to <15,000ft or engine can flame out
- If motive pump fails, then both engines are supplied from functioning feed group. (Will result in fuel imbalance)
-

IN-FLIGHT REFUELING

- Refueling flight envelope is Deck to 35,000ft, 170-300 KIAS
- Fuel transfer rate is approximately 3,000 pounds per minute (450 gallons per minute)
- Wings sweep mode should always be MANUAL
- Optimal refueling configuration is 240 KIAS with wings swept to 40°
- AFCS can be used in Controls Stick Steering with ATT HOLD (Gyro)
- ALT HOLD (Barometric) will be affect by wake from the refueling probe and be ineffective
- Refueling probe switch is powered by the DC-Essential No.2 circuit while movement of the probe is provided by the combined hydraulic system.

- Maximum probe extension speed is 400 KIAS
- Air Source is set to L ENG to prevent vapors from spilled fuel from entering the cockpit

FUEL DUMP

- Gravity pump ejects fuel at a rate of approximately 1,500 pounds per minute (225 gallons per minute)
- Order of drain is Drop tanks, Wing tank, fuselage tanks
- Dump will automatically stop when total fuel is less than 4,000lbs
- Inhibited if: Negative G, Pitch Attitude less than 0, Weight on Wheels, or if the Speed Brake Extended
- Applying afterburner during dump can torch the dump pipe (think F-111)

QTY SEL SWITCH

- Spring loaded to display FEED, hold to show WING or EXT

FEED SWTICH

- FWD, Both engines feed from forward and right engine tanks
- NORM, (default)
- AFT, Both engines feed from aft and left engine tanks

WING/EXT TRANS SWITCH

- Overide
  - Intended for use with gear down
  - Airborne, Allows transfer of wing fuel and external tanks (first to box, overflow to fuselage)
  - Weight on Wheels, Allows transfer of wing and external tank fuel
- Auto
  - Airborne AND Gear Up; Allows transfer of wing fuel and external tanks (first to box, overflow to fuselage)
  - OFF
  - Inhibits Wing and External fuel flow, Fuselage tanks lose pressurization
  - Spring returns to Auto if
    - MASTER TEST is run in INST mode
    - Fuel DUMP is selected
    - REFUEL PROBE switch is set to ALL EXTD

AB FUEL DELIVERY

- Running AB with less than 1,000lb of fuel in the respective feed tank can cause an AB blowout (FUEL PRESS warning)
- When fuselage tank is less than 2,500lb and matching feed tank is less than 1,400lbs AB use can result in AB blowout
- (TF30) It takes approximately 8 seconds to run move through all 5 stages of afterburner thrust

OXYGEN SYSTEM

- Oxygen is stored in a container with 10 liters of liquid oxygen equivalent to 8,600 liters of oxygen gas
- Oxygen is delivery regulated by the OXYGEN ON-OFF switch
- Oxygen consumption decreases with Altitude
- Based on a two man crew, 10 liters of oxygen has the following useful
  - 30,000ft - 23 hours
  - 20,000ft - 13 hours
  - 10,000ft - 10 hours
  - Sea Level - 5 hours
- Oxygen use is required above 10,000ft. While the body can survive at high altitudes with unassisted respiration, the process of physiologic accommodation takes 2-3 days. Rapid changes in altitude without supplemental oxygen can result in a state of hypoxia characterized by delirium or blackout.

ELECTRICAL POWER SUPPLY

MAIN GENERATORS

- Operate at 115-200V, nominal power output is 75kVA
- One generator is capable of supplying full AC load
- Automatically activated during engine start at ~50% N1
- Automatically resets failures if RPM drops below 30% N1

MAIN TRANSFORMER/RECTIFIERS

- Power output of 28V at 100A
- One T/R is capable of supplying full DC load
- If one T/R fails or is out of operation, then power is automatically redirected to operating T/R
- Directly power the Aircraft Flight Control System (AFCS) through interruption free bus
- Takes ~1 second to activate and power aircraft essential systems

EMERGENCY GENERATOR

- Driven by combined system hydraulic pressure
- supplies 5kVA, 115/200V to essential AC buses
- supplies 28V at 50A to essential DC buses
- Automatically activated and switched to essential AC/DC buses with loss of main DC power (regardless of generator status)
- Automatically disconnected from essential ac and dc No.2 buses in the case of a hydraulic failure, must be manually reset if hydraulic pressure recovers.
  - Fails if hydraulic drops below 1,100-2,000psi.
- Can be tested through EMERG GEN switch on Master Test Panel

EXTERNAL POWER

- Supplies power to all systems except; VDIG, MDIG, AICS, APX-76, CADC, and CSDC
- Automatically disconnected when L Generator goes online during engine start
- HYD Transfer pump will not work when external power is in receptacle

SWITCHES:

- MASTER GEN, Norm - Connects generator to main buses
  OFF/Reset - Resets overvolt, undervolt, or fault condition
  Test - Energizes generator, but does not connect to main buses
- EMERG Gen, Norm - Emergency generator is automatically connected in case of failure
  OFF/Reset - disconnects emergency generator; resets overvolt, undervolt, or fault condition.

HYDRAULIC POWER SUPPLY

ENGINE DRIVEN HYDRAULIC PUMPS

- Independent
- Normally operate at 3,000 +/- 100 psi
- Always operating if appropriate engine is running
- Hyd pressure gauge has two independent needles indicating pressure, and they form a horizontal line when both are at 3,000 psi

HYDRAULIC TRANSFER PUMP

- Provides a second source of pressure if one of the engine driven pumps fails
- A pressure deficiency in one system is augmented by the operating engine pump
- Automatically activated if pressure drops below 2,100 psi in one of the engine pumps
- Can supply 2,400 to 2,600 psi to a failed hydraulic engine pump
- If pressure in failed engine pump falls below for more than 10 seconds, then the hydraulic transfer pump is shut off

PRIORITY VALVES

- 1-way valves with activation pressure of 1,800psi and 2,400psi exist to isolate essential and non-essential systems

COCKPIT HANDPUMP

- Acts as a double action wobble pump
- Recommended rate of pumping is 12 pump cycle per minute
- Supplementary source of hydraulic power when engines are shutdown (typically on ground)
- The only means of powering the radome fold actuator
- Used to extend/retract the refuelling probe or charge the wheel-brake accumulator during in-flight emergency

ELECTROHYDRAULIC OUTBOARD SPOILER SYSTEM

- On with Right DC bus
- Deactivated at wing sweeps greater than 62 Deg
- Regulates Spoiler "ON"/"OFF" flag in the hydraulic pressure indicator

BACK-UP FLIGHT CONTROL SYSTEM

- Gives reduced rate control over main control surfaces if both engine hydraulic pumps fail
- Activates if both engine pump pressures drop below 300 psi
- De-Activate if one engine pump rises above 500psi

INDICATORS AND SWITCHES

- Note that HYD ISOL automatically goes to T.O. Land with gear lever down, but pilot manually switches to FLT position

PNEUMATIC POWER SUPPLY SYSTEMS

DESCRIPTION

- Systems consists of three independent pneumatic air sources

NORMAL CANOPY CONTROL

- Pressurized gas (typically nitrogen) is stored in rechargeable canister
- Full is 3,000psi, minimum pressure is 225 psi
- A full bottle can supply 10 open/close cycles before dropping below minimum pressure => each movement of the canopy consumes (3000-200)/(2*10) = 140psi

EMERGENCY GEAR EXTENSION

- Pressurized gas (typically nitrogen) is stored in rechargeable canister
- Full is 3,000psi, minimum pressure is 1,800 psi
- Single use per charge
- Landing gear cannot be retracted once used

AIR INLET CONTROL SYSTEM

SYSTEM DEPENDENCIES

- Electric => - AICS logical control, Essential No.2 Ac/DC bus
  => - Ramp Stow Function, Essential No.1 dc bus

OPERATION

- Two normal modes: Auto and STOW(pilot controlled through 2xSPST switch)
- AICS also serves as a back-up wing sweep controller

STOWED MODE

- Ramps retract to stowed position
  - (Failure) If a CAT launch is attempted with the inlet ramps in Stow Mode, the system Hydraulic pressure can drive the ramps out of the Stow Locks. This disrupts airflow to the turbine and is quickly followed by a compressor stall.
  - (Failure) If M>1.2 and in Stow Mode, compressor stalls can occur
  - Significantly improved ability to perform an air-start of a stalled engine in Stow Mode.
  - If AICS failure is detected (i.e. pitot blockage), reducing speed to <0.5 and cycling into STOW Mode will reset the error

AUTO MODE

- If Mach < 0.35, ramps are in stowed position (Mechanically Restrained)
- If 0.35 < Mach < 0.5, ramps are in stowed position (Hydraulic power)
- If 0.5 < Mach < 0.9, Ramps follow schedule to optimize airflow (Mach and AoA dependent)
- If 0.9 < Mach < 1.0, Ramps are in transonic position
- If 1.0 < Mach, Ramps are in supersonic position

AICS ON-BOARD

- Initiated during post-start check
- Ramps are run through an altitude and airspeed schedule(Maximum airspeed to static/Sea Level)
- Take less than 65 seconds, returns Ramps to stowed/locked position
- Test illuminates Ramp Lights
- (Failure) If Ramps are in Stow Mode, then OBC will fail and Inlet Lights will illuminate

THROTTLE CONTROL MODES

BOOST MODE

- Normal mode of operation. Reduces effort required to move throttles

AUTO MODE

- Engine Thrust is automatically regulated to maintain 15 Units Angle of Attack during landing.
- In Order to engage the Auto throttles, the following conditions must be met:
  - Engines between 78-96%RPM
  - Weight off Wheels
  - Gear Handle down
- Automatically reverts to Boost mode if 11lbs of force is applied to either throttle
  - Causes AUTO THROT light to illuminate (Caution panel is left of HUD)

MANUAL MODE

- Same as Boost Mode, but without assistance

ENGINE IGNITION SYSTEM

ENG CRANK SWITCH

- Setting the "ENG CRANK" arms redundant circuitry
- Moving Throttle from OFF to IDLE automatically begins engine start
- Above 8% N2 RPM, alternator voltage is sufficient to maintain start
- ENG CRANK switch springs back to OFF once N2 RPM is greater than 45%

AIR START SWITCH

- Selecting ON provides continuous ignition for both engines if N2 RPM is greater than 8%
- Switch must be manually returned to NORM once engines have restarted

AUTOMATIC RESTART

- Automatically engages start for 30s upon detection of a rapid decay in burner pressure.

ENGINE STARTING SYSTEM

- A 50psi air source and 115-volt power supply are required for a ground start
- 50psi can run Engine at 24% N2 RPM without ignition

ENGINE CRANKING LIMITS

- <1min for up to 5 ignition cycles each
- <2min for a single ignition cycle
- If either are exceeded, then a 5 minute cool-down period is needed

CROSSBLEED START

- Must select running engine as single air source to prevent hot start, and return to BOTH once second engine is running
- (NOT AFC 744) If a crossbleed start is used instead of ground cart, then N2 RPM must be greater than 87% to
- Provide sufficient air for cranking power.
- (AFC 744) Crossbleed start can be accomplished with running engine at idle RPM

- During a crossbleed start, throttle should be moved from OFF to IDLE at 18% N2 RPM
- If a hot start occurs, then throttle on the starting engine should rapidly be advanced to MIL power.

ENGINE OIL SYSTEM

- Each engine has a self-contained oil system which regulates pressure to 45 +/-5 psi
- Idle engine oil pressure should be 30psi
- Oil capacity is 5 gallons, with 4 useable gallons
- Oil consumption limit is 0.3 gallons per hour
- Indicated oil pressure is normally 1-1.5psi below actual oil pressure
- Oil Pressure Indicators are power by No.2 essential ac bus

ENGINE INSTRUMENTS

- Engine Stall/Overtemp Warning activated if engine TIT exceeds 1,215 deg Celsius
- Upon activation STALL flashes in the HUD at 3Hz
- Aural warning is played for 10s or until condition is cleared

INSTRUMENT TEST FROM THE MASTER TEST PANEL

- Selecting INST and depressing master test switch in the MASTER TEST panel;
    - RPM Indicator should read 80% RPM
    - TIT Indicator should read 1,300 Deg
    - FF Indicator should read 4,300 lb/h
- Selecting FIRE DET/EXT and depressing master test switch in the MASTER TEST panel;
    - L/R FIRE warning lights on
    - GO light illuminates if all tests pass
    - NO GO light if tests fail
- Selecting MACH LEV
    - Engines spool up to 81-86% N2 RPM until switch is deselected
    - GO light illuminates if all tests pass
    - NO GO light if tests fail
- \- Selecting INST
    - Fuel Quantity Indicators drive to 2,000lbs
    - L/R FUEL LOW lights illuminate
    - WING/EXT Trans Switch spring to AUTO if in the OFF position

FIRE EXTINGUISHING SYSTEM

- The FUEL SHUT OFF handle for the affected engine must be pulled before the discharge button can be pressed
- Two containers for fire retarding agent (Main/Aux) each stored at 600psi
- Single shot system, both containers empty
- Once tanks are below 90psi, ENG FIRE EXT and AUX FIRE EXT warning lights illuminate
- The lower the airspeed, the greater the possibility of extinguishing the fire