

Contingency Abort Training Manual

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Preface

This training manual is intended for self-study by Space Shuttle crewmembers, flight controllers, and instructors on the subject of Contingency Abort. It is part of a series of lessons in the training course. You should refer to the training flow to ensure that you cover the lessons in the suggested order.

This book is a general training document; all numerical data and checklist references are intended as examples.

This document has been written for the Flight Training Branch, NASA Lyndon B. Johnson Space Center, Houston, Texas.

Introduction

Contingency aborts are aborts caused by loss of more than one Space Shuttle main engine (SSME) in a region where intact abort capability is not present. Loss of one SSME plus another engine stuck at a low power setting may also require a contingency abort. Contingency abort procedures are designed to maintain Orbiter integrity throughout the abort maneuvers until a ditch at sea can be attempted.

Orbiter features supporting this abort mode include the following:

- Single-engine roll control
- Contingency orbital maneuvering system (OMS) dumps
- Fast external tank (ET) separation (SEP)

The above features, plus others required (control stick steering (CSS) and manual throttle (MAN THR)) are available only in the primary avionics software system (PASS). The backup flight system (BFS) does not support contingency abort (it does provide fast SEP in major mode (MM) 102, but no dump capability). All procedures require CSS manual guidance; no automatic guidance is provided. The objectives of the contingency abort procedures are to provide the following:

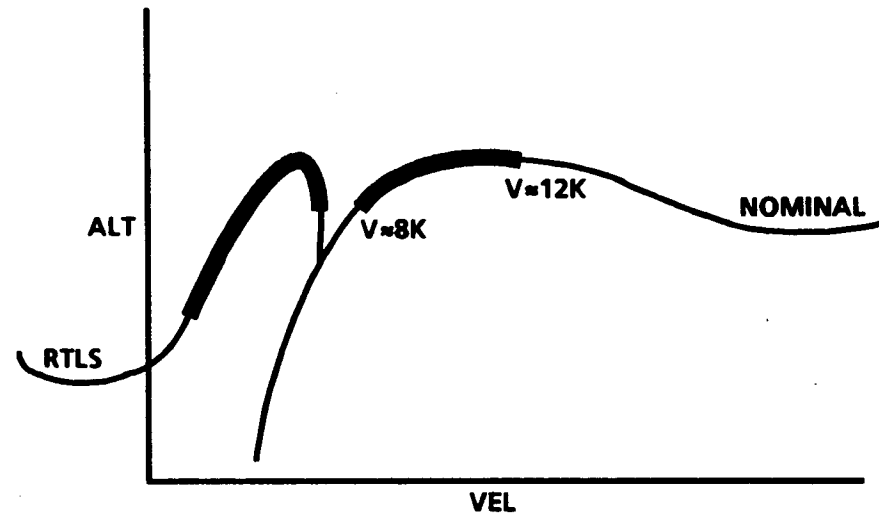
- Acceptable center of gravity (c.g.) for control purposes
- Safe ET SEP conditions
- Reduced pullout severity

Orbiter Limits

Contingency abort procedures are designed to protect the Orbiter from exceeding the following limits:

- c.g. - 1115 in.
- \bar{q} - 800 psf
- N_z - 3.5g's (mission dependent)
- Thermal - varies with structure
- ET SEP - $\bar{q} < 2$ psf

There are regions during ascent and intact abort where loss of three engines will result in violation of limits although contingency abort procedures are exercised. These regions may be flight dependent, but are, in general, as shown in figure 1.



**Figure 1.- Regions of limit violations
in three-engine loss.**

TD350*001

Single – Engine Roll Control

When two SSMEs are lost in MM 103 or 601, the vehicle cannot control all three axes of rotation with only one engine. Therefore, when the second ENG FAIL flag is set, the flight control software limits roll commands to the remaining engine and instead sends them to the reaction control system (RCS) jets. It also establishes an interconnect to the OMS, so that OMS propellant is used instead of RCS for the aft jets. Six aft roll, four aft yaw, and two forward yaw jets are used for roll control. If an intact dump (abort to orbit (ATO), return to launch site (RTLS), transatlantic abort landing (TAL)) is in progress when a second engine fails, the jets portion of that dump is terminated.

5 If two engines are lost in MM 102, the interconnect is established immediately, but jet fire commands are not issued until staging. In all cases, the interconnect will be established whether or not it is enabled or inhibited on specialist function (SPEC) 51.

If the LIMIT SHUT DN switch is in AUTO or INHIBIT when the second engine fails, the software will not recognize that the second engine is failed. Therefore, the crew must push the shutdown pushbutton for the failed engine to inform the general purpose computers (GPCs). The GPCs will then set the TWO ENG FAIL flag to enable single-engine roll control. The failed engine must be identified and the pushbutton pushed quickly, or control may be lost.

When single-engine roll is enabled, CSS pitch or yaw maneuvers should not exceed 4 deg/s or control may be lost.

The OMS/RCS interconnect automatically terminates at main engine cutoff (MECO).

Contingency Dump

During a contingency abort, OMS propellant must be dumped (burned) to move the Orbiter c.g. into an acceptable region for entry. An aft c.g. of 1109 in. is considered the limit, although the vehicle may fly with a c.g. of up to 1115 in. If the c.g. is too far aft, control will be lost during entry.

15 The contingency dump is started by the crew via SPEC 51 (ITEMS 25 and 26) and should continue automatically until completion with no further crew inputs. However, various failures could require crew intervention. The dump sequence interconnects OMS propellant to the aft RCS systems so that propellant is burned simultaneously through 2 OMS engines plus 24 RCS jets. This interconnect is required because there is generally very little time to complete the dump before entry. The interconnect is terminated at MECO if the dump is complete, or at 0.05g post-MECO if it is still occurring at that time, since the OMS cannot feed two engines plus all the jets in a g-field. If a contingency dump is occurring, and single-engine roll control is also active (which is frequently the case), roll control is maintained by turning roll jets off as required (reverse logic).

A typical contingency dump sequence is shown in figure 2.
For OI-7C, the post-MECO portion must be started manually.

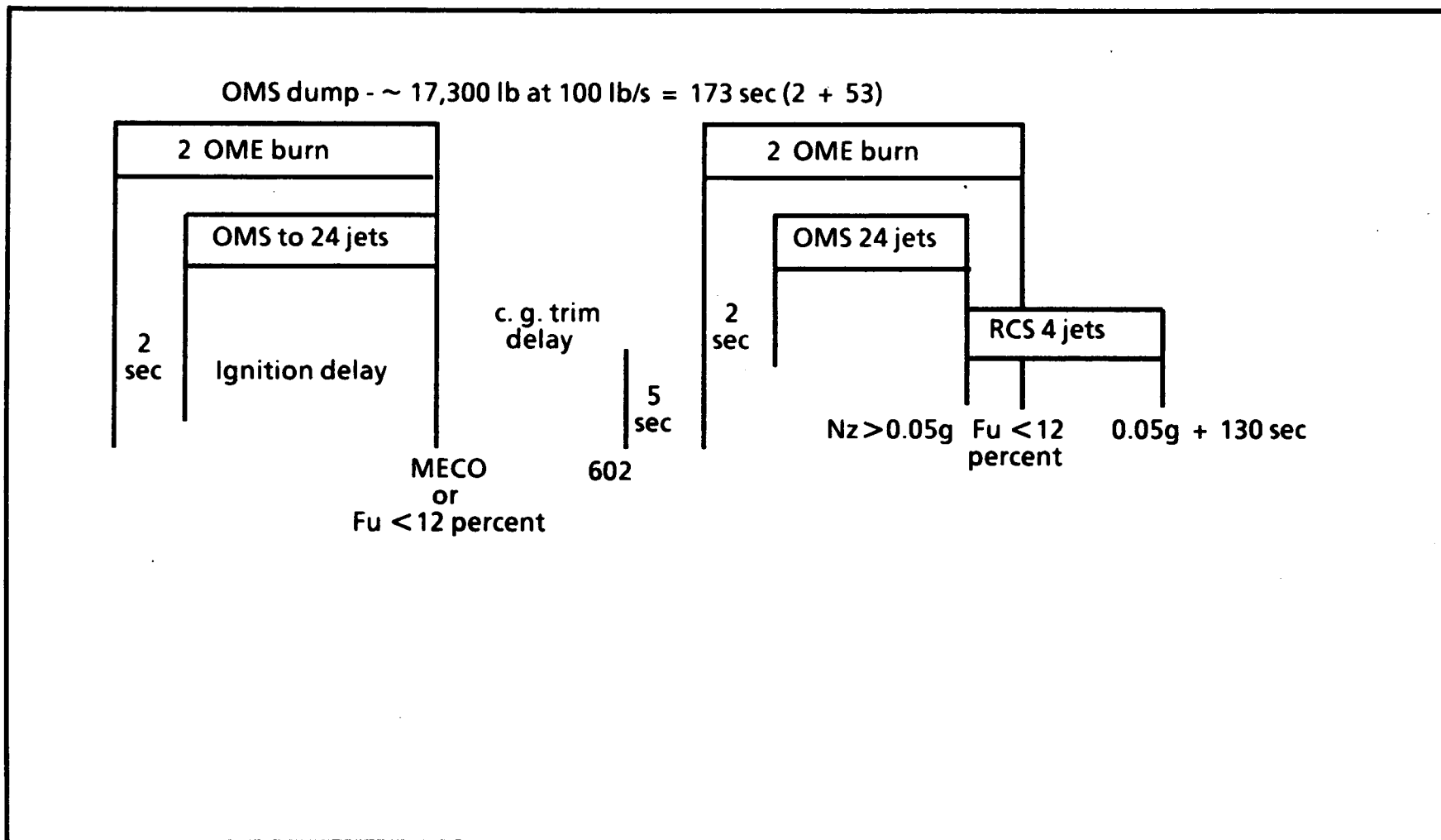


Figure 2.- Contingency dump sequence.

Fast ET Separation

The normal ET SEP sequence requires at least 12 seconds (RTLS) from MECO until ET separation. This is too long to support contingency abort procedures, which can be highly dynamic and extremely time critical. Therefore, a fast ET SEP sequence was created to support contingency aborts. The sequence is initiated by the crew's setting the ET SEP switch to manual and depressing the ET SEP pushbutton. This action shuts down operating SSMEs and separates the ET in approximately 3 seconds. (If there is a command path failure, the affected engine must be shut down with the engine power switches before pushing the ET SEP pushbutton.) In MM 102, FAST SEP also causes an operations sequence (OPS) mode transition to OPS 601, provides an automatic -Z translation, and enables a contingency dump. In OPS 601, 103, and 104, these automatic features are not provided. The BFS supports FAST SEP only in MM 102; it does not provide a contingency dump.

FAST SEP may be initiated at any time in MM 102, whether or not any engines have failed. However, it is not considered a viable mode until just prior to solid rocket booster (SRB) separation (chamber pressure $(P_c) < (50)$, when dynamic pressure is relatively low.

Also in MM 601, FAST SEP may be initiated whether or not there are engines failed. However, in MM 103, a second engine failed flag must be set before a FAST SEP can be commanded.

|∞

Controls and Displays

There is only one display or control feature unique to contingency abort. On the VERT SIT display, pullout Nz is displayed in X.X g. When the vehicle starts entry into the atmosphere and passes one g, H is snapshotted by the software, divided by 1000, and 0.5 is added to arrive at the desired g-level for pullout. This is displayed as TGT Nz on the VERT SIT display. The crew then flies this g-level, as read on the ACCEL tape, until pullout is complete (H = -250 ft/s).

Other displays and controls, not unique to contingency abort, but used to execute the procedures, are discussed below.

1. Engine status lights, Pc meters, cathode ray tube (CRT) displays and messages, ACCEL tapes

These displays and controls are used to recognize that a second or third engine has failed. Recognition must be fast and accurate so that the appropriate actions are taken by the crew in a timely manner. The correct engine shutdown pushbuttons must be depressed quickly to enable single-engine roll control. Recognition of multiple engines out can be difficult at times, and ground confirmation can be helpful.

2. Engine shutdown pushbuttons

Located on panel C3, engine shutdown pushbuttons are used to either shut down an operating engine, or inform the GPCs that a second and/or third engine has failed. In a two-engine-fail case, the procedures call for depressing pushbuttons of both failed engines. This is really not

required since the GPCs should know that the first engine has failed. However, they do not know that the second engine has failed because an automatic engine shutdown inhibit was placed on the remaining engines when the first engine failed. Therefore, the pushbutton of the second failed engine must be depressed for the GPCs to recognize a second engine failure. To avoid confusion as to which engine failed first, the crew should depress the pushbuttons of both failed engines. Likewise, for a three-engine-fail case, the crew should depress all three pushbuttons to set the MECO confirmed flag so that ET separation can occur.

3. Flight control mode switches

The switches are on the eyebrow panel, and control whether the vehicle is under automatic (AUTO) or manual (CSS) flight control. Depressing any one of the four CSS pushbuttons puts the vehicle in manual control in all axes in powered flight. Control can be from either of the rotation hand controllers (RHCs) or both (they are summed). However, the commander (CDR) normally does the flying. Hot stick downmoding is not available in powered flight.

4. Manual throttle

Manual control of engine power level is obtained (on the pilot's (PLT's) side only) by depressing the red button on the speedbrake/thrust controller (SBTC) handle, and matching the existing auto throttle level by moving the handle as required. When matching occurs, the light on the eyebrow panel changes from AUTO to MAN. At this

time, the red button can be released and the PLT has manual control of the throttles via the SBTC. A return to auto throttle can be made by depressing the AUTO pushbutton indicator (pbi). When in manual throttle, the engines must be shut down manually when MECO is desired. A guidance-commanded MECO will not occur.

Full forward on the SBTC corresponds to maximum power level, which is normally 104 percent unless MAX THR is enabled on SPEC 51, in which case full forward would command 109 percent. Full aft is 65 percent. During entry, the SBTC controls the speedbrake in the manual mode.

5. ET SEP MAN/AUTO and ET SEP pushbutton

10 These controls are located on panel C3. If the switch is in the MAN position, the ET SEP pushbutton is active and will command engine shutdown and FAST SEP as discussed previously. Auto separation will not occur if the switch is in the MAN position, unless there is an annunciated switch failure and the MM is 601.

6. Attitude direction indicator (ADI)

The ADI is a three-axis attitude indicator (eight ball) which also displays rates and steering error needles. There are three attitude references available during ascent, although only two are used (LVLH and REF). In the LVLH position, the reference frame is local horizontal, local vertical; and the ball displays pitch and roll attitudes. Yaw is pinned to zero on the ball and is instead displayed referenced to north on the horizontal situation indicator (HSI). This is the preferred mode of display during ascent since a true roll attitude is displayed. However, at high pitch attitudes (near vertical), roll becomes indeterminate and the ball oscillates and flips in roll. Since most

contingency abort procedures require near vertical thrust, it is better to select REF as the reference frame. This presents a stable, three-axis ball, and although the roll attitude displayed may not be accurate, it is generally not critical.

7. Abort rotary switch and pushbutton

These are located on panel F6 and control the abort mode and initiation. RTLS is the first position on the mode switch and is used for contingency abort entries (glide return to launch site (GRTLS) digital autopilot (DAP)). If the switch fails, RTLS may be selected via an OPS 601 (or 602) PRO on a keyboard.

8. Alpha/Mach indicator (AMI) and altitude/vertical velocity indicator (AVVI)

These are vertical tapes on each side of the ADI which display alpha, acceleration, velocity, equivalent airspeed, altitude acceleration, altitude rate, and radar altitude. The ACCEL tape switches scales from ft/s^2 in powered flight to g for entry ($20 = 2g$).

9. SPEC 51 Override CRT display

This display provides the controls for the contingency dump (and Centaur dump) and maximum throttle level (109 percent). Selecting MAX THROT is an irreversible step. A lesser throttle level cannot be reselected, except via manual throttle.

10. HSI

The HSI is below the ADI, and presents the following information relative to the horizontal plane:

- 11
- a. North on the compass card is the target plane during powered flight. A deviation from N represents a yaw attitude other than zero relative to that plane. During entry, the compass card indicates magnetic heading.
 - b. During powered flight, the course needle indicates the relative velocity vector relative to the yaw attitude of the vehicle. If the course needle is on the nose, the vehicle is headed directly along the relative velocity vector. If this needle is on the nose, and wings are level, side slip (β) is zero. During entry, the course needle indicates runway orientation.
 - c. The course deviation indicator (CDI) represents beta during powered flight. The needle should be zeroed ($\pm 5^\circ$) for MECO and ET separation. At high-pitch attitudes, rolling toward the deflected needle is the easiest way to zero beta. At low-pitch attitudes, yawing is the preferred method. During entry, the CDI is a localizer needle.
 - d. In powered flight, the primary bearing pointer is parked at 180° . The secondary pointer is the inertial velocity vector. During entry, the primary pointer points to waypoint 1 (WP1), the secondary points to the heading alignment circle (HAC) center.
 - e. PRI MILES is range to the runway threshold via WP1. SEC MILES is distance to HAC center.

11. Translational hand controller (THC)

The THC is the T-handle on panel F5 and is used to provide a -Z translation away from the ET after separation. -Z is UP on the handle.

12. ET UMBILICAL DOORS switches and talkbacks

These controls are on panel R2. If the doors do not close automatically following ET separation, the PLT should manually close them.

13. Air data sensor (ADS)

The air data probe deploy controls are on panel C3. During entry, they should be deployed at Mach 5, and the readings compared on SPEC 51. If the data looks reasonable, it should be incorporated into navigation (NAV) and guidance, navigation, and control (GNC) on SPEC 50 below 105K feet and descending, so that control of the vehicle is maintained.

14. Panel JETT T-Handle

Pulling of this handle, located on top of panel C2, causes the escape panel at the top of the cockpit to jettison. This should be done just prior to touchdown. If done after touchdown, possible cabin deformity may preclude hatch jettison.

15. SPEC 50

In addition to air data controls previously discussed, this display also provides tactical air navigation (TACAN) range and bearing data for use by rescue forces. This should be reported to the ground prior to ditching.

16. BFS TRAJ 1 display

This display provides the $P_c < 50$ cue for FAST SEP during a three-engines-out in first-stage abort. The PASS TRAJ display does not provide this cue since the PASS assumes MECO has occurred and the SRB separation task is not initiated.

17. PASS and/or BFS RTLS TRAJ display

These displays provide information along the top horizontal scale required to execute the single-engine RTLS completion procedure.

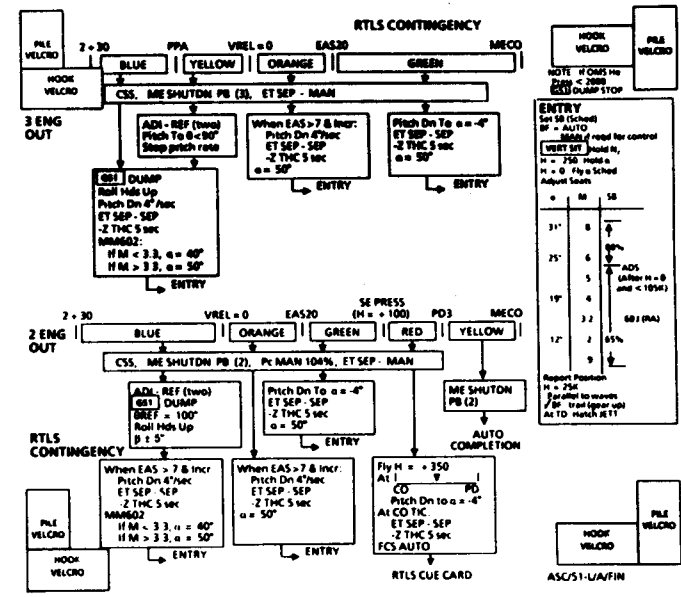
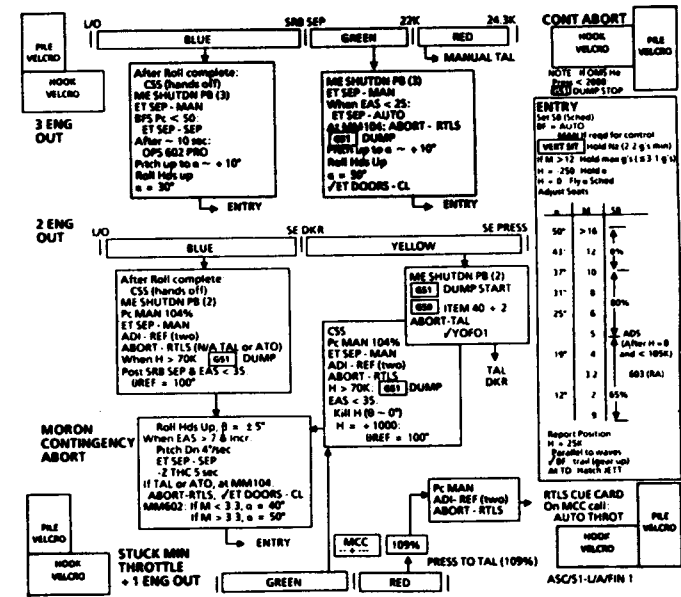
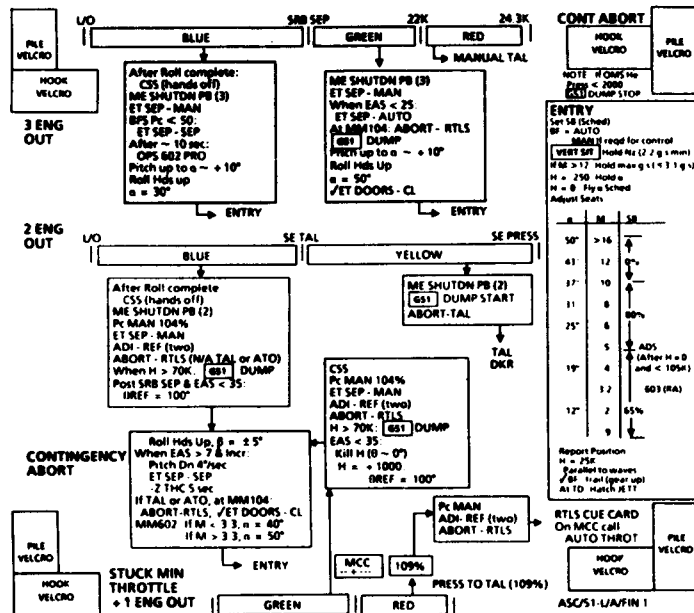
18. VERT SIT display

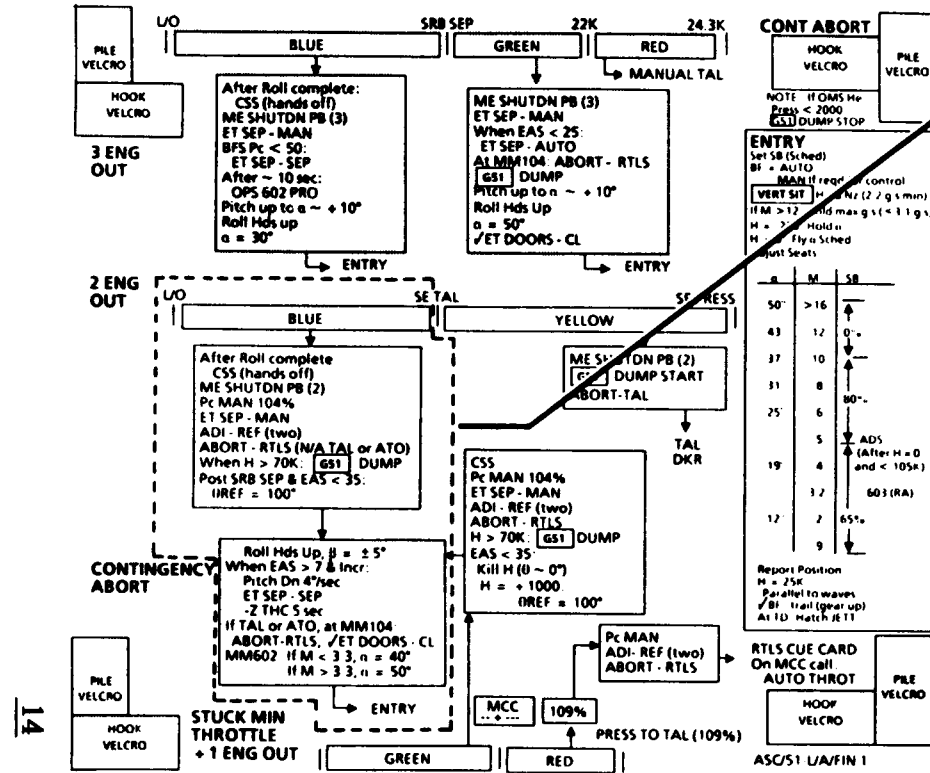
After MECO, this display provides the pullout TGT N_z required.

CONTINGENCY ABORT PROCEDURES

The contingency abort cue cards are presented below, with rationale on the pages following.

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The two-engine-out BLUE region extends from lift-off until single-engine TAL capability is reached, which is normally about 13K ft/s.

Rationale:

After Roll complete:

CSS (hands off) – CSS is required for subsequent manual steering. CSS with no manual inputs during first stage stops the pitch profile and causes the vehicle to loft so that \bar{q} is less through staging, and more OMS dump time is available prior to entry. CSS should not be

selected before the roll maneuver is complete or the vehicle flight azimuth will be in error. CSS inputs are not required and could cause excessive vehicle loads.

ME SHUTDN PB (2) – Required to inform the GPCs that two engines are failed, so that single-engine roll control is enabled. This is not a time-critical step in first stage since the SRBs are controlling, but it can be very time critical in second stage.

Pc MAN 104% – Pc MAN is required to preclude a possible early auto shutdown of the remaining engine; 104% is the abort throttle level. MAX THROT is not required.

ET SEP - MAN – This switch must be in the MAN position for a subsequent FAST SEP using the ET SEP pushbutton. It is positioned early during a relatively quiet time period.

ADI - REF (two) – A stable eight ball is required for near vertical pitch attitudes which follow.

ABORT - RTLS (N/A TAL or ATO) – This is a preparatory step so that the GRTLS DAP will be available for entry. If a TAL or ATO abort has already been selected, RTLS cannot be selected until after MECO, when the software is in MM 104. The GRTLS DAP has more control authority than the TRANS DAP.

When $H > 70K$: **G51** DUMP – The OMS engines are not designed to be burned below an altitude of 70K feet. If above 70K feet, call up SPEC 51 and start the contingency dump as soon as possible.

Post SRB SEP + $EAS < 35$:
 $\theta_{REF} = 100^\circ$ – After \bar{q} has bled off to a safe level, put in a pure pitch maneuver to 100° on the REF ball. Do not exceed 4 deg/s pitch rate.

Roll Hds Up, $\beta = \pm 5^\circ$ – Roll either way for 180° to "heads up." Then yaw to the belly-band (toward the tail of the course pointer). When yaw is reasonable, roll toward the CDI until it is centered $\pm 5^\circ$; 5° is full scale (two dots). β must be near zero for the subsequent FAST SEP so that the GRTLS DAP can maintain control.

When $EAS > 7 + \text{Incr}$:

Pitch Dn $4^\circ/\text{sec}$

ET SEP – SEP

-Z THC 5 sec

– Some \bar{q} (equivalent airspeed (EAS) > 7) is needed on the vehicle for the FAST SEP event. In many cases, \bar{q} will never get that low. When it starts increasing, and if $EAS > 7$, establish a 4 deg/s pitchdown rate. When the rate is established, depress the ET SEP pushbutton. ET separation will occur 3 seconds later. When ET SEP occurs, do 5 seconds of -Z on the THC for additional clearance and software moding to MM 104 (if GRTLS not selected). Keep the pitch rate in until $\alpha = 50$ (or 40, as required) is achieved. The software should be in MM 602 at this time if RTLS was selected pre-MECO.

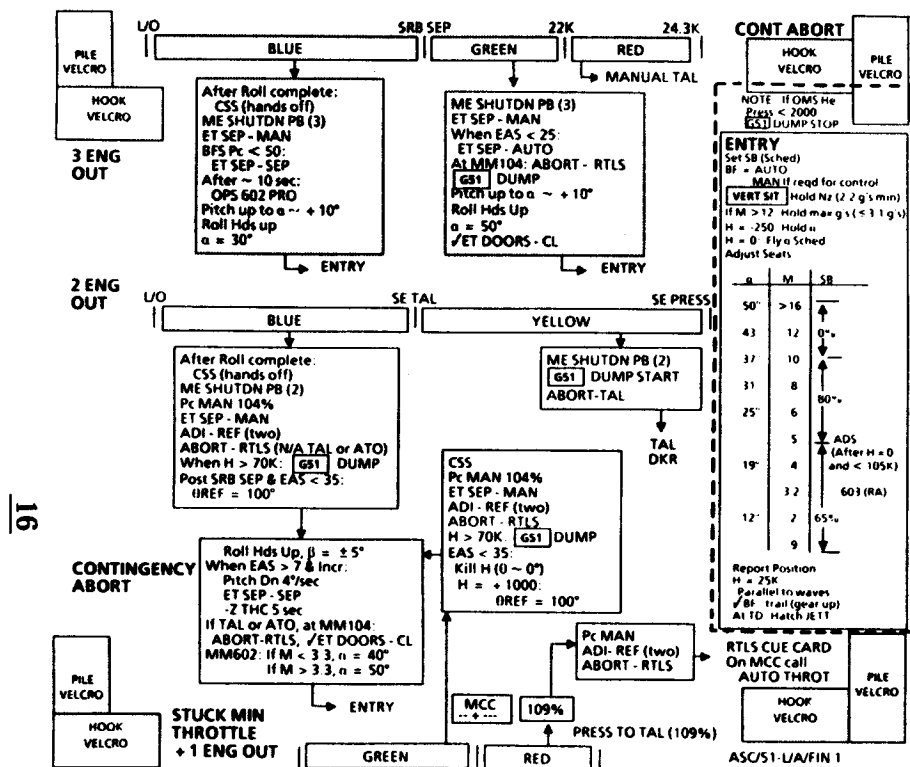
If TAL or ATO, at MM104:

ABORT-RTLS, $\sqrt{\text{ET DOORS - CL}}$ – If RTLS was not selected pre-MECO, the software should be in MM104 at this time. An ABORT RTLS will mode the software directly to MM 602. If 602 is established within 23 seconds of ET SEP, the ET doors will close automatically. If they don't, close manually.

MM 602: If $M < 3.3$, $\alpha = 40^\circ$

If $M > 3.3$, $\alpha = 50^\circ$ – The recovery is Mach dependent. Too high an α at low Mach values (and attendant steep flightpath angles) may make it impossible to follow the prescribed g profile.

 ENTRY – Go to the ENTRY section of the cue card.



This is the ENTRY section of the cue card and is applicable for all contingency abort entries except RTLS completions and manual TALs. A shortened version is used for RTLS contingency aborts since the higher Mach numbers are not encountered.

Rationale:

NOTE: IF OMS He
 Press < 2000:

G51 DUMP STOP – This is a precautionary callout to prevent starving jets needed for control. However, unless there is a secondary failure (i.e., a PROP or He leak), there is never a problem with the interconnected dump completing before 2000 psi He pressure. A more likely problem is for the vehicle to see 0.05g, terminate the interconnect, phugoid below 0.05g, and start firing uninterconnected jets using RCS fuel. This would deplete

RCS in approximately half a minute. Therefore, during entry, a close watch should be kept on RCS usage, and the contingency dump should be stopped if the above scenario occurs. A software change was made to prevent this from occurring and it apparently works. However, it is still a good idea to keep a close watch on RCS usage.

Set SB (Sched) – Guidance is not running in a downrange 602 entry. Therefore, the speedbrake (SB) must be set manually according to Mach number.

BF = AUTO

MAN if reqd for control – During most entries, AUTO BF should control the body flap as required. However, for extremely aft c.g.'s, the body flap may drive all the way down, and the elevon all the way up, thus negating elevon control. If this happens, the body flap should be set manually.

VERT SIT Hold Nz (2.2 g's min)

If $M > 12$: Hold max g's (≤ 3.1 g's) – VERT SIT should be up since it is the OPS display for 602. When the vehicle passes through one g, check TGT Nz. If it is between 2.2 and 3.1, fly that value. If it is below 2.2, fly 2.2 since that is a safe value and will reduce q. Do not pull > 3.1 (heavy Orbiter) or the wings may fail. However, it is desirable to fly that value for high-speed entries to reduce OMS pod heating. Initially, flying a g profile will require reducing α (stick forward). However, before the pullout is complete ($H\text{-dot} = -250$), back stick will be required.

$\dot{H} = -250$: Hold α

$\dot{H} = 0$: Fly α Sched – When \dot{H} decreases through -250 ft/s (approaching zero), abandon the g profile and hold the α existing at that time. The pullout is considered complete. Wait until $\dot{H} = 0$ and slowly ease to the α schedule on the cue card.

Adjust Seats – The seats have been in the launch position. Adjust as desired for ditching.

ADS

(After $\dot{H} = 0$

and $H < 105K$) – The ADS is needed for flight control. When below 105K feet and assured the vehicle will not phugoid back above 105K feet, deploy the probes, check outputs on SPEC 51, and incorporate air data to NAV and GNC on SPEC 50. Air data cannot be incorporated above 105K feet.

603 (RA) – Since guidance is not running (specifically inhibited for contingency aborts), an automatic moding to MM 603 will not occur. Therefore, the crew should do a manual OPS 603 PRO at $M = 3.2$. This is required to enable radar altimeter data to be available for ditching.

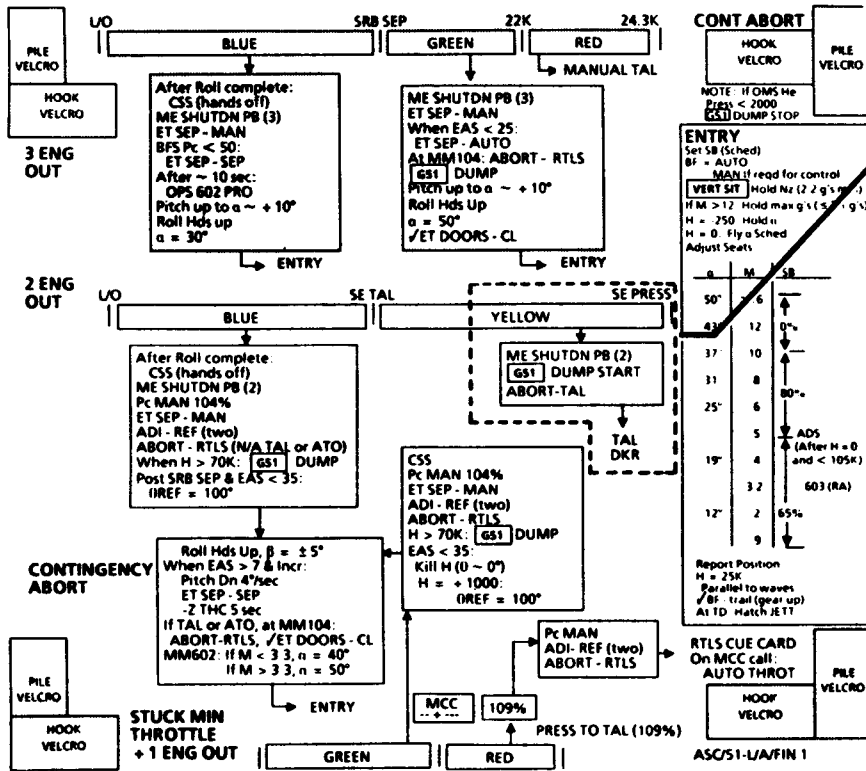
Report Position – To aid rescue forces in locating the ditched Orbiter, the crew should report TACAN range and bearing as displayed on SPEC 50 and/or range and heading from the HSI.

$H = 25K$

Parallel to waves – At 25K feet, turn to a heading parallel to waves. Fly a nominal final approach.

✓ BF - trail (gear up) – The body flap should be in trail, and the gear up, for ditching.

At TD: Hatch JETT – The escape hatch should be jettisoned just prior to touchdown, when speed is the slowest. If jettison is delayed until after touchdown, the cabin may be deformed enough to preclude a successful jettison.



The 2 ENG OUT YELLOW region extends from single-engine (SE) TAL capability until SE PRESS to MECO. This is not really a contingency abort since this procedure culminates with an intact landing at the TAL site. However, it is included because a unique procedure is required.

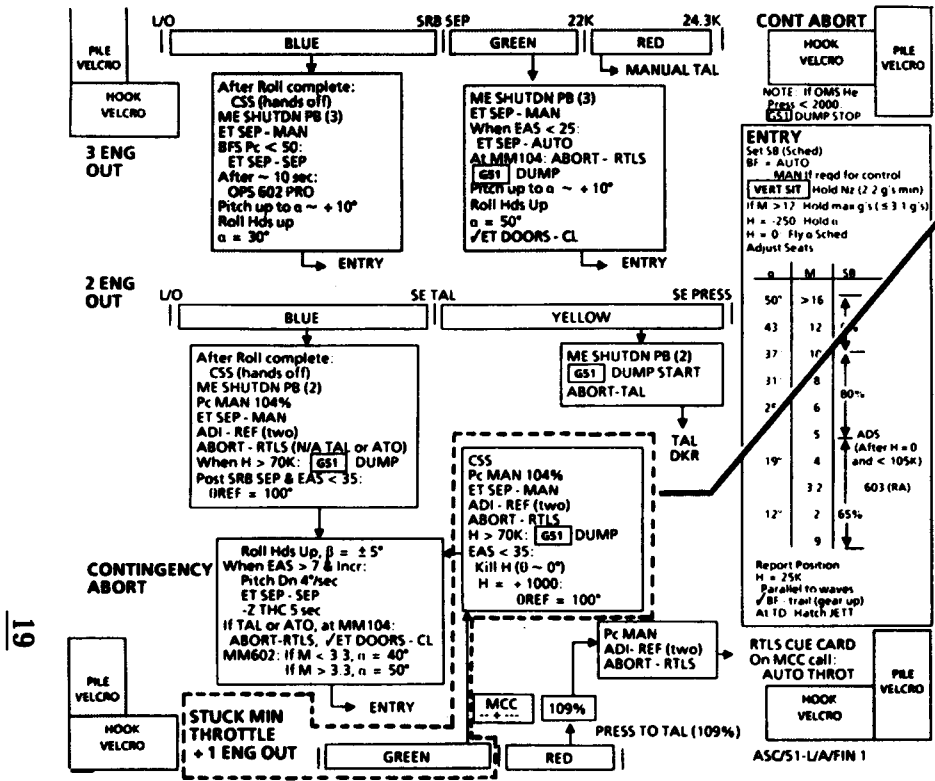
Rationale:

ME SHUTDN PB (2) – For single-engine roll control.

[G51] DUMP START – This is required because of the relatively short time available for a pre-MECO dump, and we need the 24-jet interconnected dump to achieve an acceptable c.g. The TAL dump will not fire the jets due to single-engine roll control, and there is no post-MECO TAL OMS dump.

↓
TAL
DKR – After MECO, go to the AUTO TAL procedures.

ABORT - TAL – Provides automatic TAL guidance and other features of TAL software.



The STUCK MIN THROTTLE + 1 ENG OUT GREEN procedure is valid from the time the engine is stuck in the thrust bucket until RTLS or TAL capability is reached. Rarely is there RTLS capability in this configuration except for exceptionally lightweight vehicles.

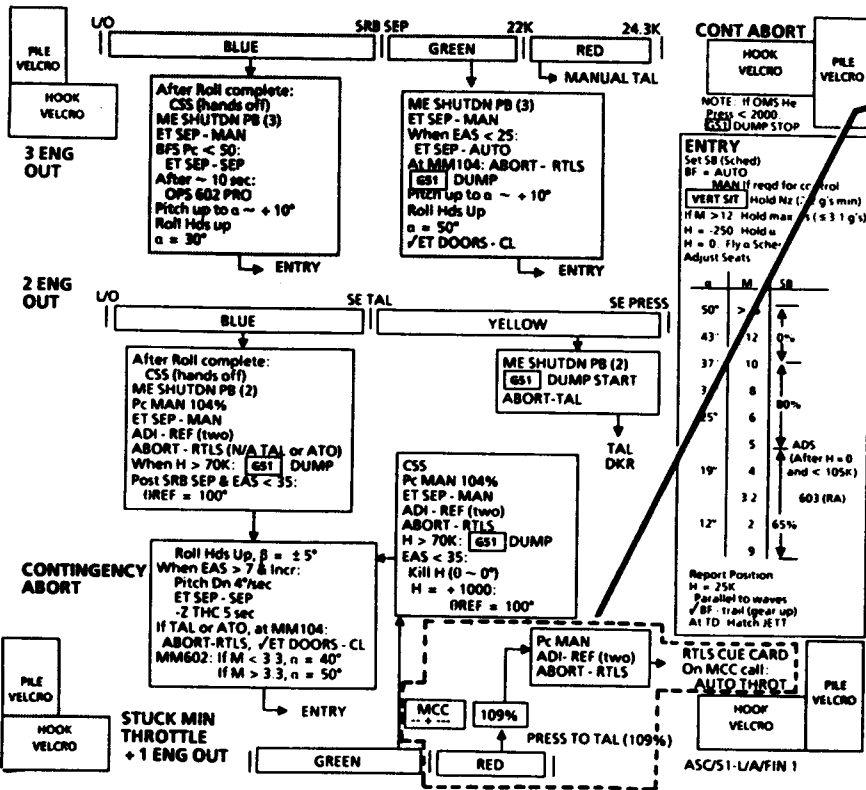
19

Rationale:

Rationale is the same as for the 2 ENG OUT BLUE section except for the following:

- Kill \dot{H} ($\theta \sim 0^\circ$)
- $\dot{H} = + 1000$
- $\theta_{REF} = 100^\circ$ - Since in this case, 1-2/3 engines are operating, more loft (altitude) will be obtained than

is desired, increasing the severity of the entry. To prevent this, the crew should (at EAS < 35) first go to a pitch attitude of approximately 0 and wait until \dot{H} has bled off to + 1000 ft/s before going to $\theta_{REF} = 100^\circ$. This usually happens very fast and stay time at $\theta = 0$ is only momentary.



The STUCK MIN THROTTLE + 1 ENG OUT RED region extends from first RTLS capability, with this configuration, to PRESS TO TAL capability. This abort results in a "nominal" RTLS with a landing on the RTLS runway.

109% – With only 1-2/3 engines going on an RTLS, 109 percent is always required to fly the RTLS trajectory. Enable MAX THR on SPEC 51.

Pc MAN – To prevent an inadvertent guidance - commanded MECO.

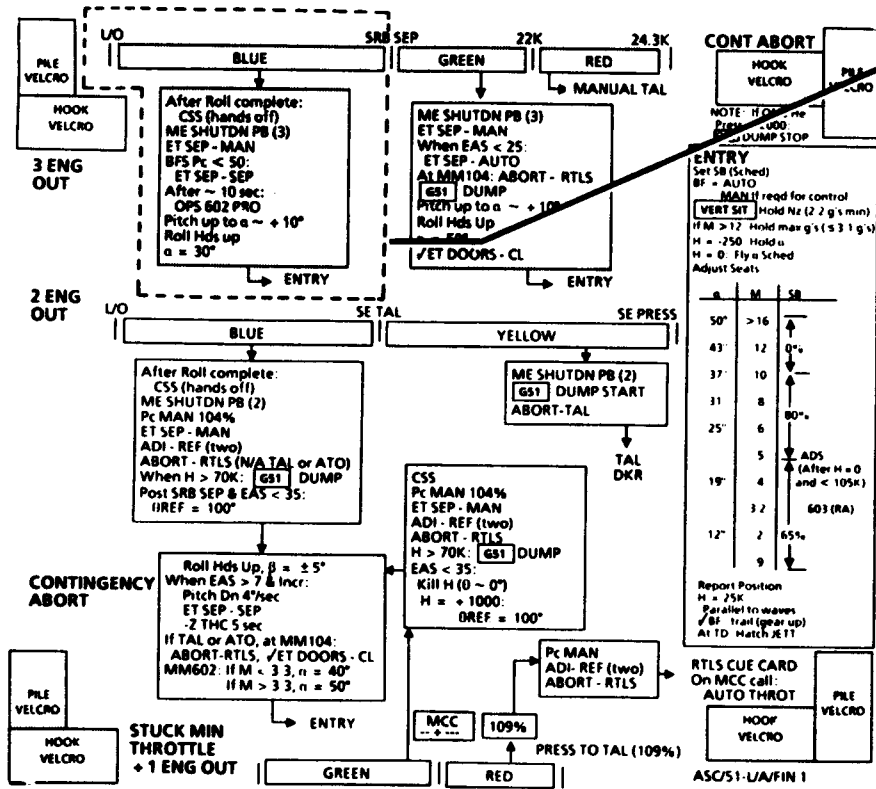
ADI - REF (two) – An RTLS with this low thrust requires near vertical thrust for an extensive period. REF provides a stable ADI.

On MCC call:

AUTO THROT – After guidance is converged and stable during flyback, MCC will call for a return to AUTO throttle so that an automatic MECO is provided at the proper time.

Rationale:

MCC -- + -- – If there is a premission determined capability for doing an RTLS with one engine down and one engine stuck at the minimum throttle bucket level, the earliest time at which this capability exists is provided in this box. If not, it is a Mission Control Center (MCC) real-time call. It is also an MCC call if the engine is stuck at some other level.



The 3 ENG OUT BLUE region is applicable from lift-off until SRB separation.

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Rationale:

After Roll complete:
 CSS (hands off)
 ME SHUTDN PB (3)
 ET SEP - MAN

} Same rationale as for 2 ENG OUT BLUE

BFS Pc < 50:

ET SEP - SEP - The PASS sees MECO confirmed, and does not initiate the SRB SEP sequence. Therefore, the separation of the Orbiter is from the ET + SRBs (stack). The best time to do this is when \bar{q} is low and yet the total vehicle is still under control. This occurs just before SRB burnout (i.e., Pc = 50). Since PASS does not run the sequence, it will not flash Pc < 50 on its TRAJ display. However, the BFS does provide this indication. Therefore, the crew must have the BFS TRAJ display up for the separation cue.

ET SEP - SEP – A FAST SEP in MM102 provides, in addition to separation, an automatic transition to OPS 601, an automatic enabling of the contingency dump, and a -Z translation away from the stack (using RCS). The -Z will continue until MM 602.

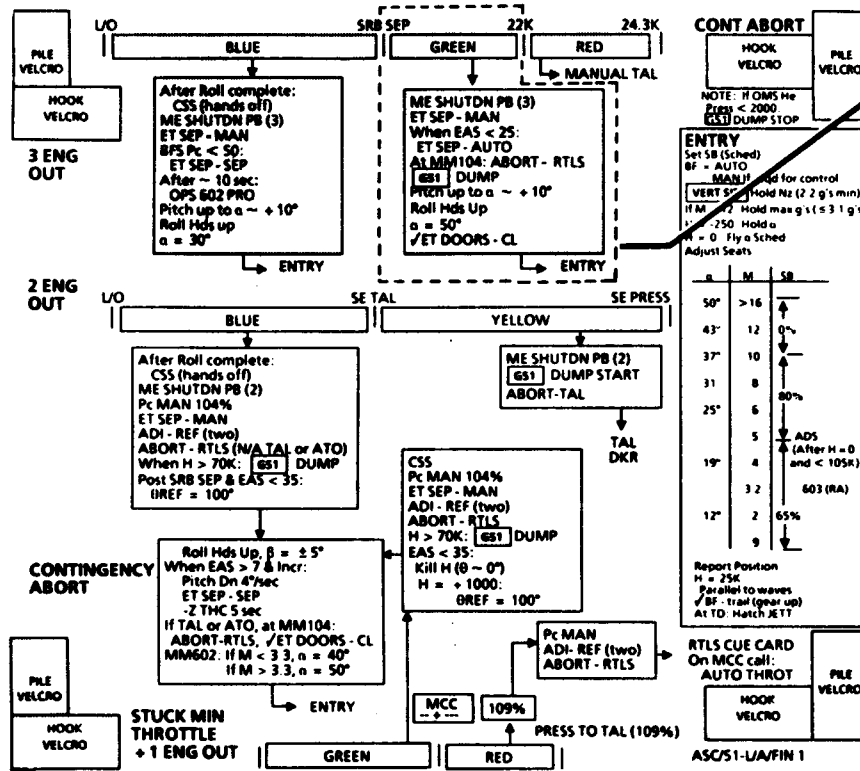
After ~ 10 sec:

OPS 602 PRO – The software will not automatically mode to 602. The crew must do this manually, after about 10 seconds for stack clearance. MM 602 starts the contingency dump.

Pitch up to $\alpha \sim 10^\circ$ – In the GRTLS DAP, roll authority is greatly reduced at low α 's. At $\alpha > 10$, full authority is provided.

Roll Hds up

$\alpha = 30$ – Proper preentry configuration. Since the flightpath angle for this entry is very steep, $\alpha = 30$ will require that the nose be well below the horizon. However, it is a relatively benign entry.

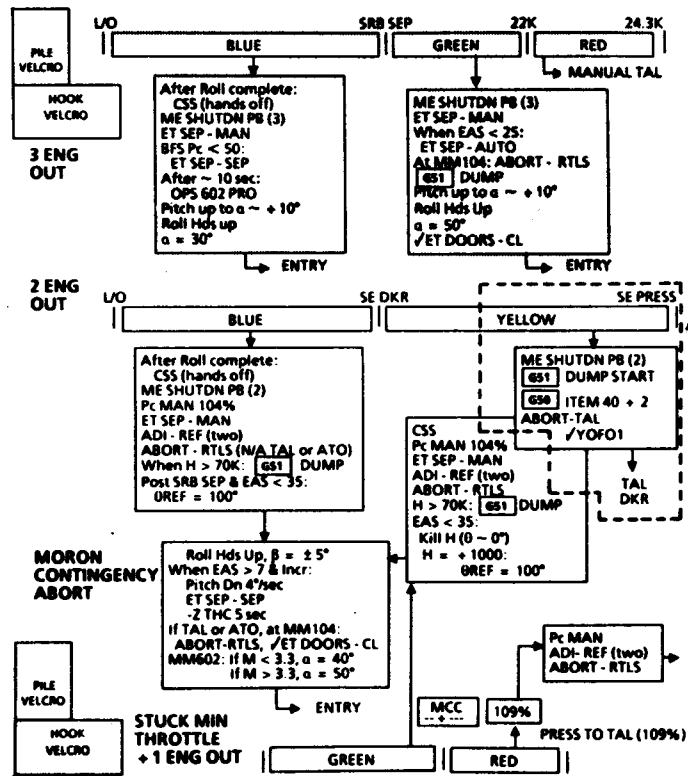


The 3 ENG OUT GREEN region extends from SRB SEP to a velocity of 22K ft/s. After 22K ft/s, manual TAL procedures would be used.

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Rationale:

The only thing unique about this procedure is, since \bar{q} will be low for an extended period during this abort, the auto separation sequence is allowed to separate the ET. This is desirable since it is an optimum sequence compared to the FAST SEP sequence. The rationale for all other steps has been previously discussed.

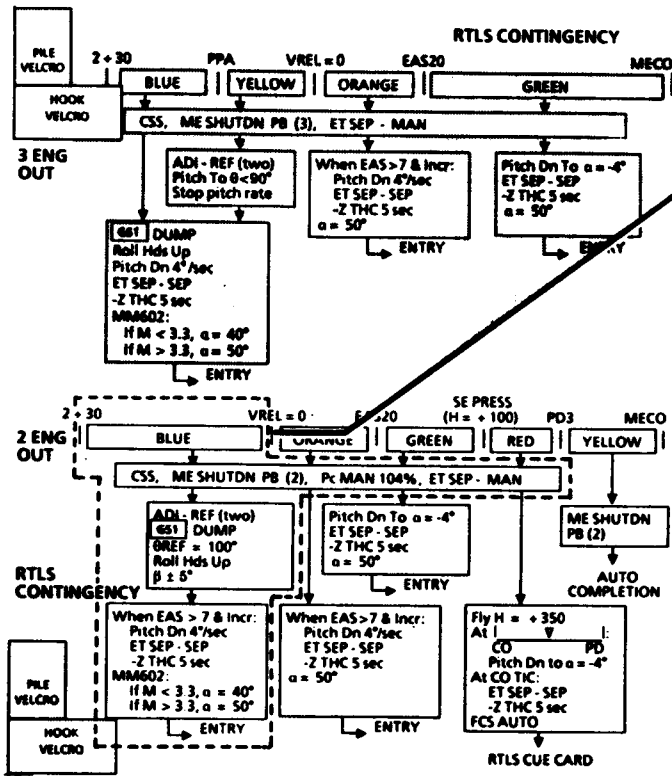


The only thing unique to the MORON CONTINGENCY ABORT card is the 2 ENG OUT YELLOW region. All other procedures on the card are identical to the regular CONTINGENCY ABORT card. The YELLOW region extends from single-engine DKR capability to single-engine PRESS to MECO.

24

Rationale:

This card assumes the out-of-plane TAL site was selected on SPEC 50 prior to lift-off because of bad weather at the in-plane site. However, in general, there is no single-engine capability to the out-of-plane site. Therefore, if two engines fail, the in-plane site must be used even if the weather is bad. This procedure provides a redesignation to the in-plane site via SPEC 50. Also, the contingency dump must be started since the jets portion of the TAL dump is inhibited with single-engine roll control in effect.



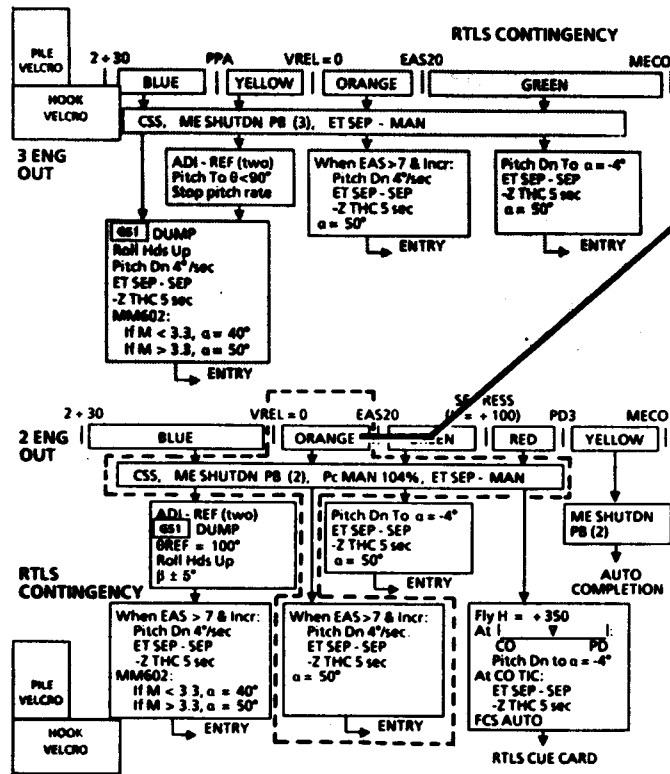
The RTLS CONTINGENCY abort card is used after an RTLS abort has been initiated. Therefore, the vehicle is already in second-stage flight since RTLS is not selected until after SRB SEP.

The 2 ENG OUT BLUE region extends from abort select to VREL = 0 during flyback.

25

Rationale:

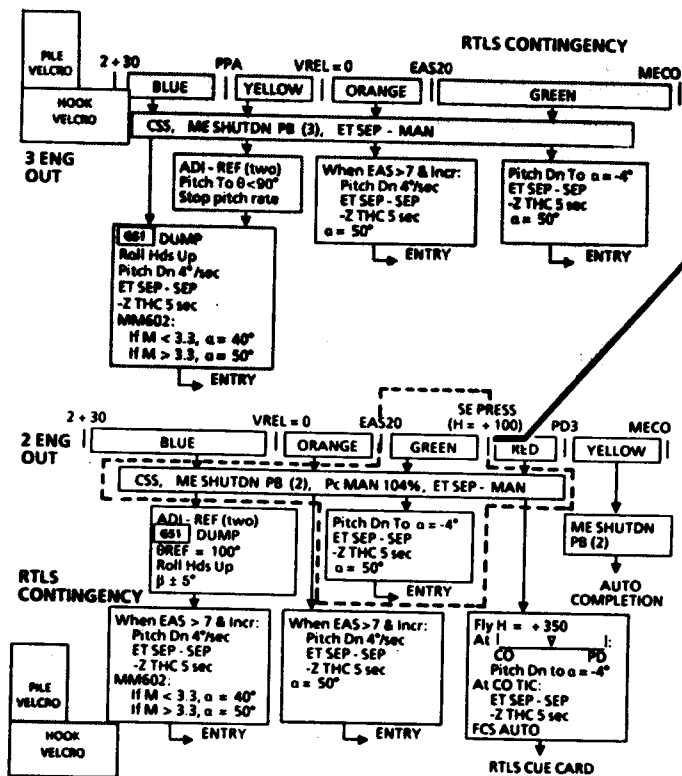
Rationale is the same as the regular contingency abort 2 ENG OUT BLUE, except for the obvious deletions. The only variable to this procedure is that, after powered pitcharound, going to $\theta_{REF} = 100^\circ$ will require a stick-back maneuver instead of forward stick.



The 2 ENG OUT ORANGE region extends from VREL = 0 to a point where EAS = 20. EAS = 20 is the limit for the high-rate ET SEP technique.

Rationale:

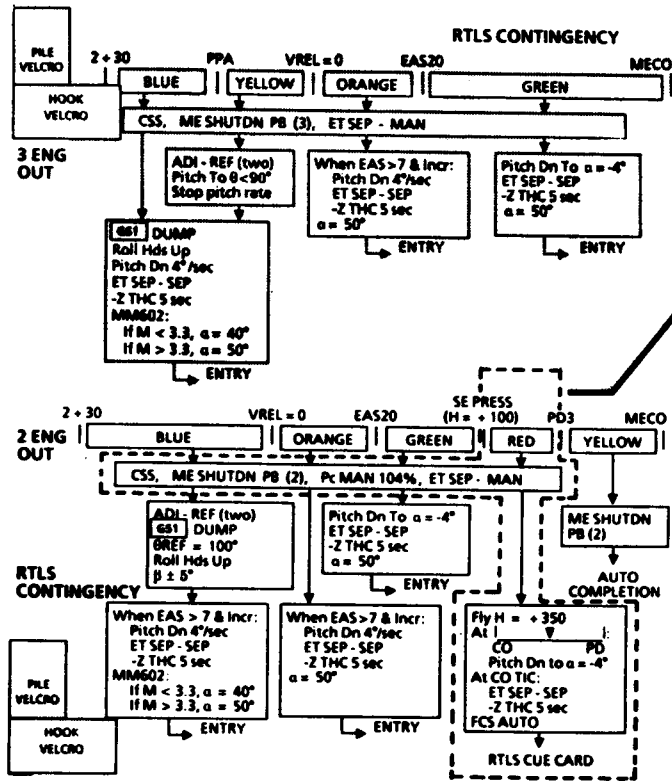
In this region, altitude is relatively low, \dot{H} is still highly negative, and \bar{q} is building rapidly. There is no time to go to a vertical thrust attitude in this region. The vehicle is also heads-up and going forward. So if EAS > 7 (and it will be for almost all this region), zero β and get off the ET, using the high-rate SEP, as soon as possible.



From the time EAS = 20 until $\dot{H} = + 100 \text{ ft/s}$, the GREEN region is applicable. This region is characterized by a high \bar{q} environment for ET SEP.

Rationale:

Since \bar{q} is too high to use the high-rate SEP technique, pitch down to $-4^\circ \alpha$, square away β , and get off the tank.



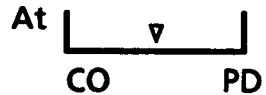
$\dot{H} = +100$ ft/s is defined as the mode boundary for an RTLS completion. The RED region extends until the cutoff (CO) bug on the RTLS TRAJ display reaches the pitchdown (PD) 3 tic mark. This procedure is designed to terminate with a landing on the RTLS runway.

28

Rationale:

CSS (and the main engine pushbuttons for roll control) must be gotten quickly for this case, else guidance will try to pitch the vehicle to a vertical attitude in an effort to achieve the RTLS targets. It is very difficult to recover from this.

Fly $\dot{H} = +350$ – When \dot{H} climbs through +350 ft/s, pitch the nose down to maintain +350. This buys performance to reach the range-velocity (R-V) target line since the thrust will become more horizontal. It also results in a smaller maneuver at PPD. The +350 is sufficient to support fast SEP at MECO.



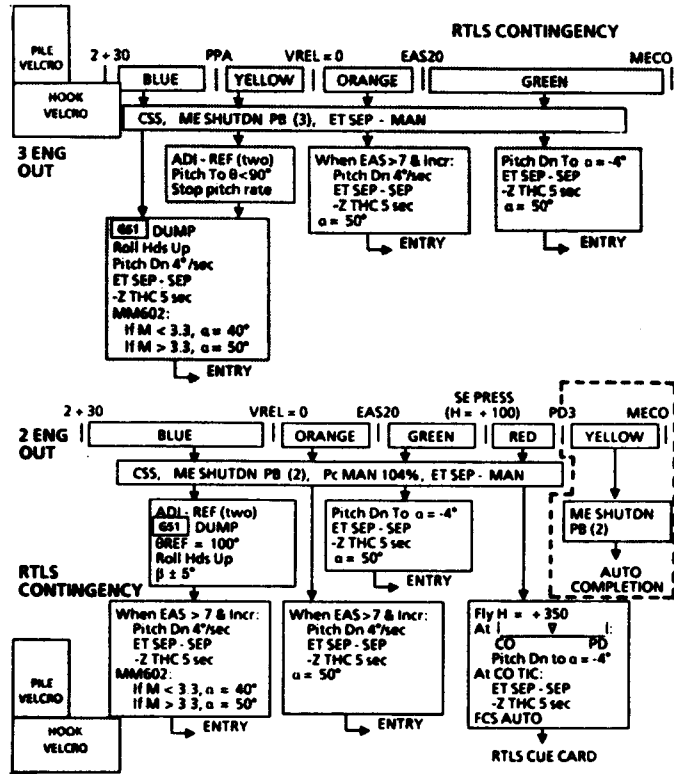
Pitch Dn to $\alpha = -4^\circ$ – When the cutoff bug on the TRAJ display reaches halfway between the PD tic and the CO tic, begin PPD. Since acceleration is slow on one engine, halfway between the two marks represents the proper time prior to MECO to begin PPD (approximately 20 seconds). Pitch down at 4 deg/s to $\alpha = -4$ and maintain. Yaw to adjust β to ≈ 0 .

At CO TIC:

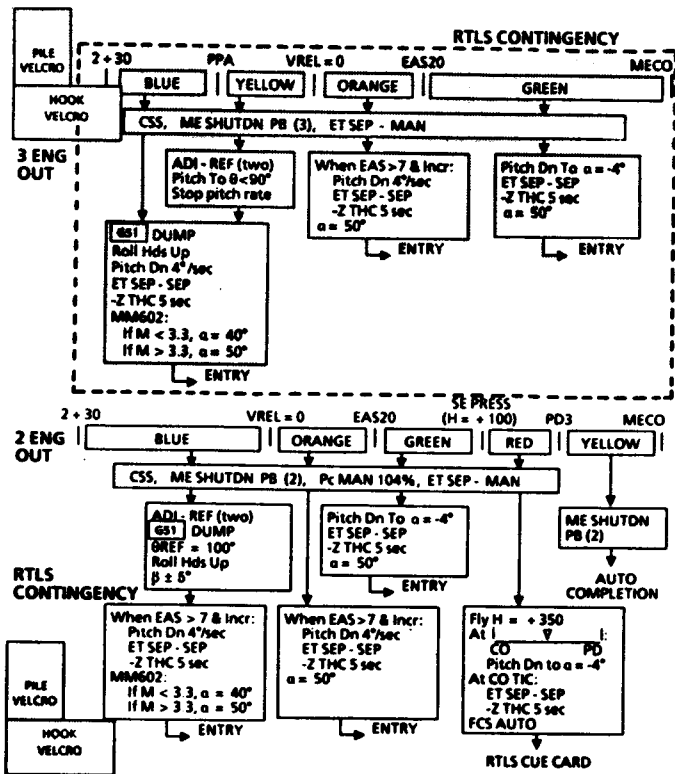
ET SEP-SEP

-Z THC 5 sec – When the bug reaches the CO tic, do a FAST SEP. This will shut down the remaining engine and separate the ET. A FAST SEP is required for this case because H was smaller at MECO than for a nominal RTLS and \bar{q} will build more quickly. There is not sufficient time to do a nominal SEP.

FCS AUTO – Auto guidance should be good for entry, although the guidance needles will be stowed because MECO occurred with unconverged guidance. This is a software quirk. Confirm good guidance with MCC.



The YELLOW region extends from the time the CO bug reaches the PD 3 tic mark until nominal MECO. If a second engine fails in this region, auto guidance should be able to complete the RTLS if it has good control. Therefore, the main engine pushbuttons are all that is required to enable single-engine roll control.



The 3 ENG OUT RTLS CONTINGENCY abort procedures contain little that is unique and needs discussion. All the steps in the BLUE region have been previously discussed.

In the YELLOW region, the vehicle is going backwards when all thrust is lost. It is better to pitch to a posigrade attitude before rolling heads up, from a control and crew orientation standpoint.

The ORANGE and GREEN regions, with the exception that manual throttle is not required, are identical to the 2 ENG OUT ORANGE and GREEN procedures, respectively.

Appendix A: Acronyms and Abbreviations

ACCEL	acceleration	H-dot	altitude rate
ADI	attitude direction indicator	HAC	heading alignment circle
ADS	air data sensor	He	helium
AMI	airspeed/Mach indicator	HSI	horizontal situation indicator
ATO	abort to orbit		
AVVI	altitude/vertical velocity indicator	JETT	jettison
BF	body flap	kt	knot(s)
BFS	backup flight system		
c.g.	center of gravity	LVLH	local vertical/local horizontal
CDI	course deviation indicator	MAN	manual
CDR	commander	MAX	maximum
CO	cutoff	MCC	Mission Control Center
CRT	cathode ray tube	ME	main engine
CSS	control stick steering	MECO	main engine cutoff
		MIN	minimum
		MM	major mode
DAP	digital autopilot	NAV	navigation
DKR	Dakar	Nz	normal load factor (g)
EAS	equivalent airspeed	OMS	orbital maneuvering system
ENG	engine	OPS	operations sequence
ET	external tank		
FCS	flight control system	PASS	primary avionics software system
		pbi	pushbutton indicator
GNC	guidance, navigation, and control	Pc	chamber pressure
GPC	general purpose computer	PD	pitch down
GRTL	glide return to launch site		

PLT	pilot	VERT	vertical
PPD	powered pitchdown	VREL	relative velocity
PRI	primary		
PROP	propellant	WP	waypoint
psf	pounds per square foot		
psi	pounds per square inch		
R-V	range-velocity		
RCS	reaction control system		
REF	reference		
RHC	rotation hand controller		
RTLS	return to launch site		
SB	speedbrake		
SBTC	speedbrake/thrust controller		
sec	second		
SEC	secondary		
SEP	separation		
SIT	situation		
SPEC	specialist function		
SRB	solid rocket booster		
SSME	Space Shuttle main engine		
TACAN	tactical air navigation		
TAL	transatlantic abort landing		
TD	touchdown		
TGT	target		
THC	translational hand controller		
THR,			
THROT	throttle		
TRAJ	trajectory		
TRANS	transition		