Project Apollo

Checklists (Standard mode)

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Introduction

This section contains all necessary procedures for a complete moon landing mission (or it will contain when it's complete...). They are provided in a similar form as the original operational procedures or the original checklists. Compared to the original documentation the content is slightly different at some places because of unavoidable differences between Project Apollo - NASSP and the historical Project Apollo. One major goal of Project Apollo - NASSP is to keep these differences as small as possible, of course. If you want to try the original documentation instead, you can download the original launch checklist by clicking on the Apollo 15 launch checklist image below, but not everything stated there is possible in Project Apollo - NASSP at the moment. See below for more links to original documentation.

Please note that the checklists are indended for scenarios with standard realism mode and are not working with "quickstart mode scenarios" (REALISM 0), for instructions/checklists to use quickstart scenarios please look here.

The checklists here are intended as a reference documentation and are no tutorial or user's guide. We'll provide additional informations in separate documents (hopefully) later.

The Apollo Guidance Computer (AGC)

A very important device of the Apollo spacecraft is the Apollo Guidance Computer (AGC), which normally does the guidance, navigation and control tasks. You interact with the AGC via the DSKY (Display and Keyboard), a kind of "terminal" for the AGC.

Project Apollo - NASSP offers two different AGC implementations: The "NASSP AGC", which is normally used and which tries to behave similar to the real AGC but is an NASSP specific program

with several differences to the real AGC. The procedures for the NASSP AGC are titled "*[NASSP AGC]*", most of the procedures in the original documentation are not working with the NASSP AGC. If you use a scenario in the "Project Apollo - NASSP\Apollo - Historical Missions" folder, for example the "Project Apollo - NASSP\Apollo - Historical Missions\Apollo 11\3. Apollo 11 - Launch", the NASSP AGC is used.

The other AGC implementation uses the Virtual AGC (http://www.ibiblio.org/apollo/index.html), an Apollo Guidance Computer emulator running the original, authentic Apollo flight software (at the moment Colossus 1A, build 249 from October 28, 1968, probably flown with Apollo 8 and 9). There are some bugs and limitations (for example max. time acceleration is about 10x, saving/loading fails sometimes), so it's still "experimental" and intended for the advanced user, who wants to have the ultimate realism, but of course with the Virtual AGC you can do all procedures exactly as described in the original documentation. The procedures and instructions for the Virtual AGC are titled *"[Virtual AGC]"* and are in blue. To try that please use the "Project Apollo - NASSP\Virtual AGC\Apollo 8 - Launch" scenario.

Procedural steps in this section are presented in tabular form and in sequence they occure during the mission. The following is a detailed explanation of the columnar data presented in the tabulated lists:


NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
(JULY 26 LAUNCH)
APOLLO 15
CSM 112
CHANGE C
CSM LAUNCH CHECKLIST
PREPARED BY
GUIDANCE & CONTROL PROCEDURES SECTION
SYSTEMS PROCEDURES BRANCH
CREW PROCEDURES DIVISION
MANNED SPACECRAFT CENTER
HOUSTON, TEXAS
JULY 9, 1971

Time This column contains the mission time the procedure is to be done. Sometimes there's no fixed time when to do a procedure, in that case the time is left out.

Procedure The procedure is a group of steps or overall tasks involved in performing a complete function or operation. It often consists of controls the astronauts have to toggle or display readings that have to be checked. You can use the panel reference if you need more informations about a certain display or control. Also the following abbreviations are used:

lt - light
sw - switch
sel - rotary type switch
cb - circuit braker
tb - talkback indicator
bp - "barber pole" (striped line indication of a talkback indicator)
vlv - valve
ind - indicator
pb - pushbutton
cont - potentiometer or rheostat
tw - thumbwheel

Additionally to use the DSKY the following abbreviations are used: V is short for VERB, N is short for NOUN, and E is short for ENTR.

Panel The panel number of a particular switch or display for easier panel navigation.

Remarks Any useful comment. Please notice especially differences to the original function, bugs or other issues.

Prelaunch checklist

In Project Apollo - NASSP the Saturn prelaunch checklist starts at 3 hours before launch with the backup crew in the spacecraft. At first some of the spacecraft's systems have to be activated.

Time	Procedure	Panel	Remarks

-03:00:00	*C/W system activation* C/W POWER - 1 (up) MASTER ALARM pb/lt (3) - on, push	2	The suit compressor alarm is normal.
	CMC power up cb G/N COMPUTER MNA - close cb G/N COMPUTER MNB - close	5	Activation of the command module computer.
	[NASSP AGC] Wait until DSKY light test complete STBY lt - on PRO STBY lt - out Key N00E P00 NO ATT lt - on Key V34E Key V16 N33E	2	Light test isn't historically correct. Run program 0, the AGC idling program. IMU is not turned on. Show launch countdown (not historically correct).
	[Virtual AGC] V37E 00E P00 If prog alarm, check if alarm code 1520 "V37 request not permitted at this time" by V05N09E, then RSET and retry V37E 00E V35E F 88 88 V37E 00E V16 N65E 16 65 V37E 00E	2	Run program P00 This can happen every V37 request. Light test Shows time since power-up, check time synchronization with Orbiter.
	IMU power up cb G/N IMU HTR MNA - close cb G/N IMU HTR MNB - close cb G/N IMU MNA - close cb G/N IMU MNB - close *[NASSP AGC]* NO ATT lt - off *[Virtual AGC]* NO ATT lt - on (90 sec) NO ATT lt - off	5 2	Activation of the inertial measurement unit.

When it's possible, the original Apollo documentation is used for this checklist. The *Apollo Operations Handbook Block II Spacecraft - Volume 2 Operational procedures reference* (see below) is one of the major sources for the checklists as it is for the following procedure, but also the original checklists are used to gather the necessary informations.

With the first procedure the caution and warning system is checked.

STA/T	STEP	PROCEDURE	PANEL	REMARKS
		4.1 BACKUP CREW PRELAUNCH CHECKS		
		Prelaunch procedures consist of operational and configuration checks performed by backup flight crew prior to ingress of prime crew. Procedures have been sequenced so they can be more easily compared with other prelaunch documents. In order to keep them closely aligned, redundant switch settings may appear in more than one area and GDC align procedures have been repeated wherever necessary. It is assumed that a complete prelaunch checkout, including loose gear stowage, has been performed by ground support personnel, prior to backup crew ingress into command module, and that all systems are in an active configuration as required at time of ingress. Spacecraft suit circuit shall have been purged and oxygen content verified to be 95% minimum. Backup crew will utilize facility headsets until service structure is clear of vehicle, as there will be no VHF AM or S BAND transmission until that time. Refer to Appendix B for cabin switch/control position prior to backup crew cabin ingress.		
		4.1.1 C&WS STATUS CHECK		
CMP		C/W NORM - NORM	2	
		C/W CSM - CSM		
		C/W PWR - 2 [pause at off (ctr) at least 1 sec]		Excessive switching speed will cause temporary loss of both power supplies, and alarm reset capability.
ALL		MASTER ALARM pb/lt (3) - on, push	1,3,122	
CMP		C/W PWR - 1 [pause at off (ctr) at least 1 sec]	2	Excessive switching speed will cause temporary loss of both power supplies, and alarm reset capability.
ALL		MASTER ALARM pb/lt (3) - on, push	1,3,122	
CMP		C/W LAMP TEST - 1 (hold)	2	1 position is momentary.
CDR		MASTER ALARM pb/lt - on	1	
CMP		lh C/W lt (15) - on	2	
		C/W NORM - BOOST		
CDR		MASTER ALARM pb/lt - out	1	
CMP		C/W NORM - NORM	2	
CDR		MASTER ALARM pb/lt - on	1	

STA/T	STEP	PROCEDURE	PANEL	REMARKS
CMP		C/W LAMP TEST - 2 (hold)	2	2 position is momentary.
CDR		MASTER ALARM pb/lt - out	1	
CMP		lh C/W lt (15) - out	2	
LMP		MASTER ALARM pb/lt - on	3	
CMP		rh C/W lt (20) - on	2	
		C/W LAMP TEST - rel		
LMP		MASTER ALARM pb/lt - out	3	
CMP		rh C/W lt (19) - out	2	SUIT COMPR C/W light will remain on until compressor is activated.
		C/W NORM - ACK		

Next the primary and secondary water-glycol coolant loops are checked and the primary water-glycol coolant loop is activated. The grey lines indicate displays or controls which are not available at the moment, please ignore these steps.

STA/T	STEP	PROCEDURE	PANEL	REMARKS
		4.1.3 GLYCOL LOOP CHECKS		
		Sec Gly Loop Check		
CMP		GLY TO RAD SEC vlv - NORM	377	
		ECS IND sel - SEC	2	
		SEC COOL PUMP - AC1		
		RAD SEC IN TEMP ind - 60°-97°F		
		RAD SEC OUT TEMP ind - 60°-70°F (pegged)		
		SEC GLY EVAP OUT TEMP ind - 60°-75°F (pegged)		
		SEC GLY EVAP STM PRESS ind - 0.25 psia (pegged)		
		SEC GLY DISCH PRESS ind - 39-51 psig		
		SEC ACCUM QTY ind - 30-50%		

STA/T	STEP	PROCEDURE	PANEL	REMARKS
CMP		SEC COOL PUMP - AC2	2	
		SEC GLY DISCH PRESS ind - 39-51 psig		
		SEC COOL PUMP - off (ctr)		
		ECS IND sel - PRIM		
		GLY TO RAD SEC vlv - OVP	377	
		Prim Gly Loop Activation		
LMP		GLY PUMPS - 2 ACl	4	
CMP		PRIM GLY DISCH PRESS ind - 37-50 psig	2	GSE flow must be temporarily interrupted (3 minutes maximum) for this check.
		PRIM ACCUM QTY ind - 25-50%		
LMP		GLY PUMPS - 1 ACl	4	
CMP		PRIM GLY DISCH PRESS ind - 37-50 psig	2	
		RAD FLOW CONT PWR - PWR		
		RAD FLOW CONT AUTO - 2		
		ECS RAD tb - 2		2 indicates No. 2 flow proportioning valve controlling flow.
		RAD FLOW CONT AUTO - AUTO		
		ECS RAD tb - gray		Gray indicates No. 1 flow proportioning valve controlling flow.
		RAD FLOW CONT PWR - off (ctr)		
CDR		DIRECT O2 vlv - OPEN (CCW), adj for	7	
CMP		O2 FLOW ind - 0.4±0.1 lb/hr	2	

Next the third inverter and the fuel cell radiators are checked.

Time	Procedure	Panel	Remarks
	C/W NORM - BOOST	2	

STA/T	STEP	PROCEDURE	PANEL	REMARKS
	4.1.4	STANDBY INVERTER (NO. 3) CHECK		
LMP		AC2 RSET - OFF	3	
		INV 3 - MNB		
		INV 2 AC2 - OFF		
		INV 3 AC2 - on (up)		Rapid performance of inverter switching sequence may initiate MASTER ALARM pb/lt when alternate inverter is connected to bus.
LMP		AC2 RSET - RSET	3	RSET position is momentary. Positioning AC1 or 2 RSET switches to RSET and releasing ensures a MASTER ALARM light and tone. Positioning AC1 or 2 RSET switches to center will cause random activation of MASTER ALARM lights and tone.
CMP,LMP		MASTER ALARM pb/lt (2) - on (push)	3,122	
CMP		C/W lts (34) - out	2	
LMP		AC IND sel - BUS 2, ØA, B, C	3	
		AC VOLTS ind - 113-117 vac		
		AC2 RSET - OFF		
		INV 3 AC2 - OFF		
		INV 2 AC2 - on (up)		Rapid performance of inverter switching sequence may initiate MASTER ALARM pb/lt when alternate inverter connected to bus.
		AC2 RSET - RSET		RSET position is momentary. Positioning AC1 or 2 RSET switches to RSET and releasing ensures a MASTER ALARM light and tone. Positioning AC1 or 2 RSET switches to center will cause random activation of MASTER ALARM lights and tone.
LMP,CMP		MASTER ALARM pb/lt (2) - on (push)	3,122	
CMP		C/W lts (34) - out	2	
LMP		INV 3 - OFF	3	Inverter 1 powering a-c bus No. 1 and inverter 2 powering a-c bus No. 2.
		AC IND sel - BUS 1 & 2, ØA, B, C		
		AC VOLTS ind - 113-117 vac		
	4.1.5	FC RADIATOR & FLOAT BAG CHECKS		
		FC Rad Check		
CMP		cb FC RAD (all) - close	226	
LMP		FC RAD tb (all) - gray	3	Gray indicates fuel cell radiator panels not bypassing flow.
CMP		cb FC RAD (all) - open	226	
		Float Bag Check		
CDR		FLOAT BAG (all) - OFF	8	Lever lock.
		cb FLOAT BAG (all) - close		
		FLOAT BAG (all) - VENT		Lever lock.
		cb FLOAT BAG (all) - open		

Next some checks regarding the panel displays and controls have to be done and a few but very important devices have to be turned on. We begin at panel 325, which is to the left of the left side panel.

Time	Procedure	Panel	Remarks
	PRIM GLY TO RAD vlv - NORM	325	
	AUTO RCS (16) - OFF SECS LOGIC (both) - OFF SECS PYRO ARM (2) - SAFE cb pnl 8 - all closed except cb CM RCS HTRS (both) - open cb FLOAT BAGS (all) - open cb SECS LOGIC (2) - open cb SECS ARM (2) - open	8	
	EDS PWR - OFF TVC SERVO PWR (both) - OFF FDAI/GPI POWER - BOTH LOGIC 2/3 PWR - on (up) ELEC PWR - GDC/ECA SIG CONDR/DR BIAS PWR (both) - AC1 or AC2 BMAG PWR (both) - WARMUP	7	 Turn on both FDAIs. Turn on GDC and ECA. Powers RJ/EC. Switches should not be set on same bus.
	CMC ATT - IMU ACCEL - check (+1 G) FDAI SCALE - 5/1 FDAI SEL - 1/2 FDAI SOURCE - CMC ATT SET - GDC MAN ATT ROLL - RATE CMD MAN ATT PITCH - ACCEL CMD MAN ATT YAW - RATE CMD LIM CYCLE - OFF ATT DBD - MIN RATE - HI THC PWR - on (up) RHC PWR NORM (both) - AC/DC RHC PWR DIR (both) - OFF SC CONT - SCS CMC MODE - FREE BMAG MODE (3) - RATE 2 ATT SET TW (3) - R 162°, P 90°, Y 0° ELS LOGIC - OFF ELS AUTO - AUTO CM RCS LOGIC - OFF CM PRPLNT DUMP - OFF CM PRPLNT PURG - off (down) IMU CAGE - off (down) α/Pc IND sw - α α/Pc ind - zero LV IND/GPI sw - GPI EVNT TMR START - ctr EVNT TMR RSET - up (ctr)	1	 Activate Trans. Contr. Pwr. Activate Rot. Contr. Pwr. These are the nominal values for a 72° launch azimuth. Guarded. Guarded. Guarded. Guarded. Switch to α. Event timer not counting. Timer resets and starts automatically when lift-off occurs.
	SUIT CAB ΔP ind - > + 2.0 inH_2O O_2 FLOW ind - 0.4 ± 0.1 lb/hr	2	 Gray indicates probe fully

	PROBE EXTD/REL tb (2) - gray PROBE (3) - OFF RCS status check SM RCS He 1 tb (4) - bp SM RCS He 2 tb (4) - bp SM RCS PRIM PRPLNT tb (4) - bp SM RCS SEC PRPLNT tb (4) - bp EDS AUTO - OFF CSM/LM FNL SEP (both) - off (down) CM/SM SEP (2) - off (down) SIVB/LM SEP - off (down) PRPLNT DUMP - AUTO 2 ENG OUT sw - AUTO LV RATES sw - AUTO TWR JETT (both) - AUTO LV GUID sw - IU LV STAGE - OFF XLUNAR INJECT - INJECT MN REL - off (down)		extended or retracted. Barber pole indicates valves are closed. Guarded. Guarded. Guarded. Guarded. Guarded. Guarded. Guarded.
	FC 1 PUMPS - AC1 FC 2 & 3 PUMPS - AC2 MN BUS TIE (2) - OFF BAT CHGR - AC1 cb pnl 5 - all closed	5	
	GLY PUMPS - 1 AC1 SUIT COMPR (both) - OFF cb pnl 4 - all closed	4	

The last part of the panel checks is again from the *Apollo Operations Handbook Block II Spacecraft - Volume 2 Operational procedures reference* (see below).

STA/T STEP	PROCEDURE	PANEL	REMARKS
	RH MDC Pnls		
	FC RAD (all) - off (ctr)	3	
	FC RAD tb (all) - gray		Gray does not indicate status of fuel cell radiator bypass valves as talkback circuits are not powered at this time.
	FC HTRS (all) - on (up)		
	FC PURG (all) - OFF		
	FC REACS (all) - ctr		
	FC REACS tb (all) - gray		Gray indicates fuel cell reactants valves open.
	FC MNA 1 & 3 - OFF, 2 - ctr		Fuel cell management will be monitored by ground crew until the gimbal drive and trim check at which time they will be verified on the main buses by the crew.

RH COUCH CHECKS

STA/T	STEP	PROCEDURE	PANEL	REMARKS
LMP		FC MNA 1 & 3 tb - bp, 2 tb - gray	3	Barber pole indicates fuel cells 1 and 3 disconnected from main bus A, gray indicates fuel cell 2 connected to main bus A.
		MNA RSET - ctr		
		FC MNB (all) - OFF		
		FC MNB tb (all) - bp		Barber pole indicates all fuel cells disconnected from main bus B.
		MNB RSET - ctr		
		FC IND sel - 1, 2, 3		
		FC H2 FLOW ind - 0.01-0.05 lb/hr		Flow limits are proportional to individual fuel cell currents and can be approximated by fuel cell H2 flow ≈(amps x 2.5)/1000, and fuel cell O2 flow ≈(amps x 2.0)/100. CSM is supplying most of the SC power.
		FC O2 FLOW ind - 0.1-0.4 lb/hr		
		FC SKIN TEMP ind - 390°-450°F		
		FC COND EXH TEMP ind - 150°-175°F		
		FC tb (2) - gray		Gray indicates normal pH factor and normal fuel cell radiator temperature.
		FC IND sel - 2		
		BAT CHG - OFF		
		DC IND sel - FC 1, 2, 3		
		DC AMPS ind - 5-20 amps		
		DC IND sel - MNA, B		
		DC VOLTS ind - 26.5-31 vdc		
		DC IND sel - BAT BUS A, B, BAT C		
		DC VOLTS ind - 35-37.5 vdc		
		DC AMPS ind - <3.0 amps		

STA/T	STEP	PROCEDURE	PANEL	REMARKS
		CAUTION		
		Do not leave DC IND sel at PYRO BAT A (B) position any longer than req to read DC VOLTS, or PYRO bat chg will be depleted.		
LMP		DC IND sel - PYRO BAT A, B	3	
		DC VOLTS ind - 36.0-37.5 vdc		
		DC IND sel - MNA		
		Dual Inv Stat Check		Switch position verification only. If switch positions must be changed, refer to 4.5.3.9, step a.
		INV 1 - MNA		
		INV 2 - MNB		
		INV 3 - OFF		
		INV 1 AC1 - on (up)		
		INV 2 AC1 - OFF		
		INV 3 AC1 - OFF		
		INV 1 AC2 - OFF		
		INV 2 AC2 - on (up)		
		INV 3 AC2 - OFF		
		AC IND sel - BUS 1 & 2, ØA, B, C		
		AC VOLTS ind - 113-117 vac		

STA/T	STEP	PROCEDURE	PANEL	REMARKS
CMP		MSN TMR - RSET	2	RSET position is momentary.
		MSN TMR ind - zero		
		MSN TMR - START		Will reset to zero and count up at lift-off, but not abort initiation.
		MSN TMR ind - counting up		
		C/W NORM - ACK		
		C/W CSM - CSM		
		C/W PWR - 1 (verify)		
		C/W LAMP TEST sw - ctr		
		PL VENT VLV - push (lock)		
		CRYO H2 PRESS ind (both) - 225-260 psia		

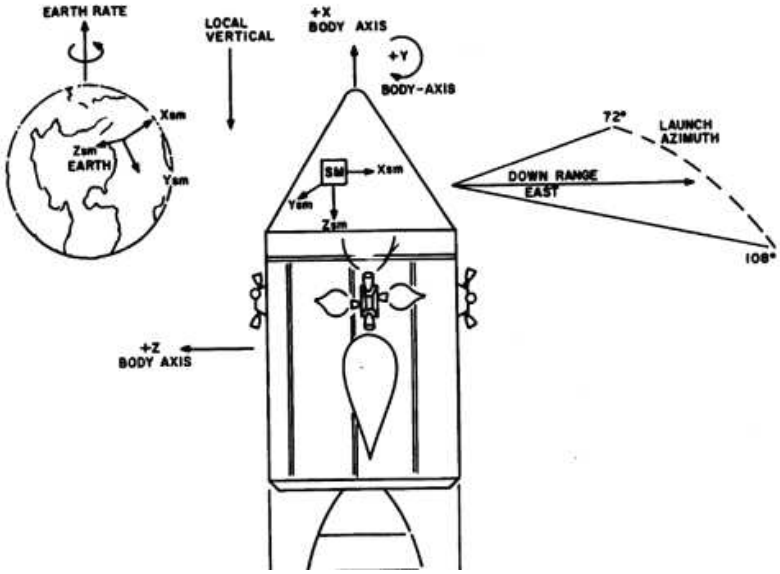
RH COUCH CHECKS

STA/T STEP	PROCEDURE	PANEL	REMARKS
C+P	O2 PRESS IND sw - SURGE TK	2	
	CRYO O2 PRESS 1 ind - 865-935 psia		
	O2 PRESS IND sw - TK 1		
	CRYO O2 PRESS ind (both) - 865-935 psia		
	CRYO H2 QTY ind (both) - 100%		
	CRYO O2 QTY ind (both) - 100%		
	CAB FAN (both) - OFF		
	H2 HTRS (both) - AUTO		
	O2 HTRS (both) - AUTO		
	O2 PRESS IND sw - SURGE TK		
	H2 FANS (both) - AUTO		
	O2 FANS (both) - AUTO		
	ECS IND sel - PRIM		
	RAD PRIM IN TEMP ind - 60°-97°F		
	RAD PRIM OUT TEMP ind - 35°-50°F		
	PRIM GLY EVAP OUT TEMP ind - 35°-50°F		
	PRIM GLY EVAP STM PRESS ind - 0.25 psia (pegged)		
	PRIM GLY DISCH PRESS ind - 60 psig max		
	SUIT TEMP ind - 45°-55°F		
	CAB TEMP ind - 70°-80°F		
	SUIT PRESS ind - ≈14.9 psia		
	CAB PRESS ind - ≈14.7 psia		
	CO2 PP ind - 0.0 mm Hg		
	RAD FLOW CONT AUTO - AUTO		
	ECS RAD tb - gray		Gray indicates No. 1 flow proportioning valve controlling flow.
	RAD FLOW CONT PWR - off (ctr)		
	RAD MAN SEL - RAD 1		When switch is powered, by placing RAD FLOW CONT PWR switch to MAN SEL, center position will close all isolation valves.

4.1.11 RH COUCH CHECKS

STA/T STEP	PROCEDURE	PANEL	REMARKS
CMP	RAD PRIM HTR - off (ctr)	2	
	RAD SEC HTR - OFF		
	SUIT COMPR ΔP ind - 0.0 psid		SUIT COMPR C/W light remains on as long as compressors are not operating.
	PRIM ACCUM QTY ind - 25-50% min		
	H2O QTY IND sw - WASTE		
	WASTE H2O QTY ind - <80%		
	H2O QTY IND sw - POT		
	POT H2O QTY ind - 80%		
	POT H2O HTR - OFF		
	SUIT H2O ACCUM AUTO - ctr		
	SUIT H2O ACCUM ON - ctr		
	SUIT HT EXCH - ON for 20 sec then off (ctr)		Unless SUIT HT EXCH control switch is positioned to off (center), continuous power will be applied to motor valve.
	SEC COOL EVAP - RSET for 58 sec min, then off (ctr)		Ensures secondary loop steam pressure valve closed.
	SEC COOL PUMP - off (ctr)		
	GLY EVAP IN TEMP - MAN		
	Position prim loop stm press vlv		
	GLY EVAP STM AUTO - MAN		
	GLY EVAP STM INCR - INCR for 58 sec min, then DECR for 8.5±0.5 sec		INCR and DECR positions are momentary. Steam pressure valve requires 58 seconds from full close to full open.
	GLY EVAP H2O FLOW - off (ctr)		
	CAB TEMP - MAN		
	CAB TEMP tw - max decr		

Now the prelaunch programs of the CMC are started, the DSKY is used for that. If you use the Virtual AGC, during prelaunch the IMU platform, also called stable member (SM), is aligned to launch position. This is shown in the following figure:



The NASSP AGC does no gyro-compassing in P02 yet, so the IMU drifts in earth rate like the GDC. At lift-off the IMU is aligned again, so the IMU attitude in flight is fine.

Time	Procedure	Panel	Remarks
[NASSP AGC]			
	Start program P01 Key V37 N01E NO ATT lt - on NO ATT lt - off	2	Start P01 "Prelaunch or service initialization program".
	Change to P02 F 06 29 PRO		Verb 06, noun 29 shows the desired launch azimuth in format XXX.XX°, press PRO to confirm.
	F 06 44 PRO		Noun 44 shows shows in R1 the desired apoapsis and in R2 the periapsis altitude, both in format XXXX.X m, press PRO to confirm.
	F 06 33 Key V16E 16 33		Noun 33 shows time to lift-off, hours in R1, minutes in R2 and seconds in R3. Verb 16 monitors the countdown, that means the DSKY updates the time every 2 seconds. (not historically correct)
[Virtual AGC]			
	Start program P01 Key V37E 01E NO ATT lt - on Course align IMU NO ATT lt - off Change to P02	2	After starting P01 "Prelaunch or service initialization program" the IMU changes to course align mode and drives the stable member to prelaunch position. Then it changes automatically to P02 "Prelaunch or service gyro compassing program". Because the AGC commands during P02 are very small you can't see them at the FDAI, but you can monitor the IMU gimbal angles with **V16 N20E**.
	Optional *check/change of launch azimuth* Key V78E F 06 29 R1: Launch azimuth To proceed press PRO, to change: Key V21E F 21 29		The AGC did a prelaunch alignment for the launch azimuth as it is stored in the scenario. If you like, you can check or change it. This is done with verb 78, the DSKY shows the present launch azimuth. Press **PRO** to continue without changing, with verb 21 you could "load component 1 into R1" and change the launch azimuth in the format +XXX.XX°. Press **PRO** to confirm the new setting. Press **CLR** to clear a wrong input.

	Key +XXXXXE F 06 29 Key PRO Pulse gyros...		
	... to new launch position.		After pressing **PRO** the AGC changes the attitude of the stable member with gyro pulses to the new launch azimuth.

The computer is running and ready for launch.

Prime Crew Ingress/Cabin Closeout

Now the spacecraft is ready for prime crew ingress and cabin closeout. In real Apollo prime crew ingress began at T-02:40:00 and ends with closing the hatch at T-01:40:00. In between the prime crew did a lot of checks similar to the backup crew checks above.

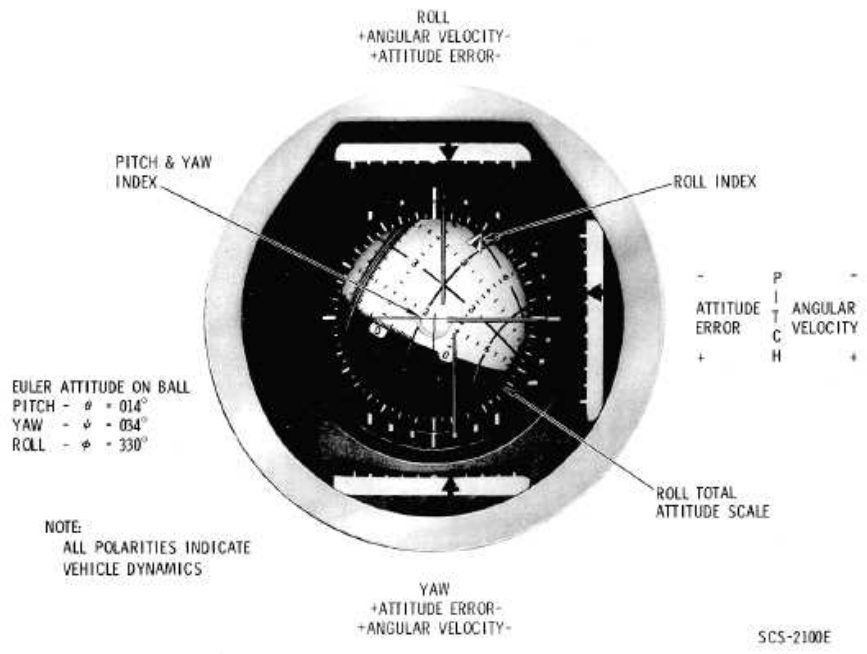
In Project Apollo - NASSP as a simplification both events happen simultaneously and take place at T-01:40:00, the prime crew checks are left out. If you use time acceleration the simulation slows down automatically at that time and some audio of the prelaunch is played. Please make sure that you do the following steps directly or shortly after T-01:40:00.

Time	Procedure	Panel	Remarks
-01:40:00	*Prime crew ingress and cabin closeout* C/W NORM - NORM DIRECT O_2 vlv - OPEN, adj for O_2 FLOW ind - 0.6-0.8 lb/hr SUIT COMPR 1 - AC1 SUIT COMPR lt - out SUIT COMPR ΔP 0.7-0.9 psi SUIT CAB ΔP ind - > +2.0 inH_2O SUIT H_2O ACCUM AUTO - 1 Verify P02	 2 7 2 4 2	 After about 10 minutes.

Now the prime crew continues with the final system checks before launch. At the beginning the BMAGs (Body Mounted Attitude Gyro) are turned on, the FDAIs and the GDC (Gyro Display Coupler) are checked and the GDC is aligned to the reference attitude for a typical launch azimuth. The CSM has 2 independent devices, which provide an inertial attitude reference, the IMU and the GDC by using the BMAGs. The IMU was aligned by P01/P02, now the GDC is aligned.

The FDAI

To display the various attitude informations the FDAI is used. The FDAI shows three things simultaneously: the total attitude, the attitude rate and the attitude error in respect to a defined other attitude by using the error needles.



Christophe, who is pilot by profession, explains the FDAI (and the ORDEAL) like this:

"I'm a pilot and what is very disturbing for pilots is that we understand the FDAI as an artificial horizon similar to those we know in aircraft. But in fact, although the Apollo FDAI has the same purpose than a classic horizon (to display the attitude) the goal, the operation and above all the reference are quite different.

First, you have to consider that the system is composed of 2 FDAI that are identical and of 2 subsystems for giving the reference: The main one is the Inertial Measurement Unit (IMU) which could be summarized as an inertial platform. The second and backup one is Gyro Display Coupler (GDC) using BMAGs which are body mounted attitude gyros. Both of the FDAI could be coupled either on the IMU or on the GDC while the standard mode is FDAI 1/IMU and FDAI2/GDC.

Second, depending on which phase of the mission you are, the display you need is not always the same. And while a spacecraft is not really flying above the surface like an aircraft does, but is orbiting around a planet, the "zero reference" (I mean that you read "pitch 0°", "bank 0°" and "ball centered") is not necessary when the spacecraft is nose on the horizon, "wings" at level and pointing toward the heading.

However, astronauts of the days of Apollo were mainly pilots and wanted to have some displays as close as they used to see on an airplane flying in atmosphere. So they used two main different mode of display:

The first one is called "Inertial stellar". That means that the reference is a 3D system of coordinates which is fix relative to the stars. That does not mean that there's only one system of reference. In fact there's is one system of reference almost for each mission phase: Some of them are used many time during the flight and in order to be activated several time they are stored in the computer as some "REFSMMAT" for REference For Stable Member Matrix. If you use the Virtual AGC, you can activate those REFSMMAT while doing IMU realignment Program P52 or P54 (option 3 "REFSMMAT").

Some others are used only once for specific maneuver, in fact one for each burn and they are computed in real time by the computer while in prethrust program and could be activated too by the P52 or P54 program (option 1 "preferred"). The purpose of this latest is to display the zero reference (wings at level and "ball centered") just when the spacecraft is steady at the burn attitude. In this case, if there is something wrong with the autopilot when the burn as started and the spacraft commence to drift in a wrong attitude, it's more easy for the astronaut to manually control the ship and to come back to the right attitude wich correspond to the 0° in each axis.

There are other specific systems of reference for attitude, like "lunar landing" for example.

You understand easily that, if the reference is fix relative to the stars, the display will be fix too. So if for example your spacecraft is orbiting around the earth and for some reason you want to orient it in a fix attitude relative TO THE EARTH SURFACE (that's what you call "surface relative" in orbiter way

of speaking) for example because you want to turn the window and maintain it toward the ground and take some shots, the FDAI will rotate slightly as you are orbiting. Just because it is fix to the star and "you" (the ship) is not. That's something which doesn't disturb the scientists and engineers who think with their brains, but that is totally inacceptable for you and me as some pilots who "thinks with their guts" as well as the astronauts themself. That the reason why the NASA developped the second mode of display: ORDEAL.

ORDEAL means Orbit Rate Drive Earth And Lunar (You sometimes find Orbit Rate Drive Electronics Apollo L... something I've forgotten). It's an additionnal box installed near the left hand window inside the command module. This box could be set to automatically rotate the coupled FDAI around the pitch axis at the same rate of the orbital period. This means that, while the ship is orbiting around the earth (or moon) and rotating on itself in order to have always the same side turning toward the surface, the ORDEAL FDAI displays a FIXED reference attitude. Almost exactly like if you were sitting on a aircraft flying on atmosphere. According to the historical Apollo flight plans, the Ordeal mode was the standard one used while orbiting around earth or moon, except for the burns and rendezvous maneuvers.

For the end, concerning the others displays you can find on the FDAI there are:

Errors needles: The yellow ones accross the ball that are like cross bar of a Flight director : they have the same purposes and are of "go to" type. But take care of the source they come from!

Rate needles: the little triangles near the balls that indicates the rotating rates of the spacecraft."

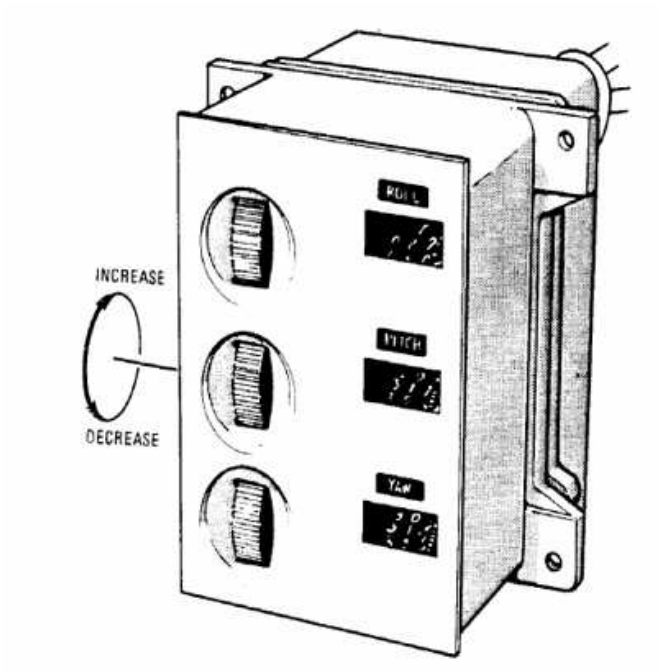
The following table explains what the FDAIs show with the different switch settings. At first the CMC ATT switch is always switched to IMU, the GDC position is a backup for the CMC attitude, but was never used and so is not explained here. On the left side you see the various settings for the FDAI SEL, FDAI SRC and ATT SET switches, "(any)" means the FDAI readings don't depend on that switch. On the rigth side it is explained what attitude and error the FDAIs show, the following abbreviations are used:

- IMU: Current total attitude indicated by the IMU
- GDC: Current total attitude indicated by the GDC
- (null): No Attitude, FDAI is off.

- CMC: Error needles are controlled by the CMC, readings depend on the CMC program (the DAP for instance).
- BMAG1: If BMAG 1 is uncaged in attitude hold mode (ATT1/RATE2 mode) the error needles show the difference between the GDC attitude and the BMAG 1 attitude.
- IMU/ASCP: The error needles show the difference between the IMU attitude and the attitude currently set in the ASCP (see below).
- GDC/ASCP: The error needles show the difference between the GDC attitude and the attitude currently set in the ASCP.

Switch Settings			FDAI 1		FDAI 2	
FDAI SEL	FDAI SRC	ATT SET	Attitude	Error	Attitude	Error
1/2	(any)	(any)	IMU	CMC	GDC	BMAG1
1	CMC	(any)	IMU	CMC	(null)	(null)
1	GDC	(any)	GDC	BMAG1	(null)	(null)
1	ATT SET	IMU	IMU	IMU/ASCP	(null)	(null)
1	ATT SET	GDC	GDC	GDC/ASCP	(null)	(null)
2	CMC	(any)	(null)	(null)	IMU	CMC
2	GDC	(any)	(null)	(null)	GDC	BMAG1
2	ATT SET	IMU	(null)	(null)	IMU	IMU/ASCP
2	ATT SET	GDC	(null)	(null)	GDC	GDC/ASCP

With the ASCP (Attitude Set Control Panel), located in the lower left corner of the main panel, you can enter a total attitude by using the thumbwheels:



If you click with the left mouse button on the upper/lower part of the thumbwheel, the attitude gets 1° bigger or smaller. Hold down the mouse button for continuous change. A click with the right mouse button changes 0.1° in the corresponding direction.

Finally the GDC ALIGN pushbutton stores the attitude currently set in the ASCP in the GDC, so with that you can change the GDC attitude manually and this is done in the following.

STA/T STEP	PROCEDURE	PANEL	REMARKS
	4.2.2 FINAL VERIFICATION & SYSTEMS CHECKS		
	4.2.2.1 G&C Verification		
-01:13:00			
	1 Gyro Pwr Up		
	C/W NORM - NORM		
	BMAG TEMP lt (both) - out		
CDR	FDAI/GPI PWR - OFF	7	If FDAIs are powered when BMAGs come up to speed, rate needles will oscillate full scale.
	ELEC PWR - GDC/ECA		
	BMAG PWR (both) - ON		
	FDAI/GPI PWR - BOTH		
CMP	C/W NORM - ACK	2	
	2 GDC Align		
CDR	FDAI SEL - 1	1	
	FDAI SOURCE - ATT SET		

STA/T STEP	PROCEDURE	PANEL	REMARKS
CDR	ATT SET tw (3) - R 162°, P 90°, Y 0°	1	These are nominal angles for a 72° launch azimuth and agree with prelaunch TCP. Only roll is affected by a variable launch azimuth.
	GDC ALIGN pb - push		
	FDAI 1 - err null		
	ATT SET tw (3) - R 168°, P 81°, Y 359°		
	FDAI 1 - full scale err (verify)		
	R right, P up, Y right		
	FDAI SEL - 2		
CMP	FDAI 2 - ind same as FDAI 1 (verify)	2	
CDR	GDC ALIGN pb - push	1	
CMP	FDAI 2 - err null	2	
CDR	ATT SET tw (3) - R 162°, P 90°, Y 0°	1	
CMP	FDAI 2 - full scale err (verify)	2	
	R left, P down, Y left		
CDR	FDAI SEL - 1	1	
	FDAI 1 - ind same as FDAI 2 (verify)		
	GDC ALIGN pb - push		
	FDAI 1 - total att (verify)		
	R 162°, P 90°, Y 0°		

Now the main bus supply is configured for flight. During prelaunch and up to now the main bus power is supplied by the GSE (Ground Support Equipment), only Fuel Cell 2 is connected with Main Bus A. GSE is disconnected at T-15 min, so we have to power both buses with the fuel cells before that.

Time	Procedure	Panel	Remarks
	Main bus activation FC MNA 1 & 2 - up, 3 - OFF FC MNA 1 & 2 tb - gray, 3 tb - bp FC MNB 1 & 2 - OFF, 3 - up FC MNB 1 & 2 tb - bp, 3 tb - gray	3	Up position is momentary. Up position is momentary.

Next the FDAIs are set in flight configuration, the GDC attitude is aligned to the IMU attitude and the pyros and sequential systems are armed.

STA/T STEP	PROCEDURE	PANEL	REMARKS
LMP	MN BUS TIE (2) - OFF, then AUTO	5	
CDR	TVC SERVO PWR (both) - OFF	7	
	LV IND/GPI sw - SII/SIVB	1	
	4.2.2.3 FDAI Verification		
	FDAI SEL - 1/2		
	FDAI SOURCE - CMC		
	FDAI 1 - total att R X°; P 90°; Y 0°		FDAI 2 is drifting as a function of earth rate.

STA/T STEP	PROCEDURE	PANEL	REMARKS
CDR	Align GDC to IMU		Ensures that GDC is aligned to actual IMU angles, rather than calculated values. Attitude reference comparison (in orbit) will be more accurate.
	FDAI SEL - 1	1	
	FDAI SOURCE - ATT SET		Constraint: If CMC is on, an overload in IMU resolver circuitry may cause an ICDU oscillation and trigger ISS warning light. (Reference ICD MH01-01325-216.) FDAI must be used as a null meter in this mode of operation. If not, large errors will result because of impedance mismatch.
	ATT SET - IMU		
	ATT SET tw (3) - null FDAI 1 err		
	ATT SET - GDC		
	GDC ALIGN pb - push		
	FDAI SOURCE - CMC		
	FDAI SEL - 1/2		
-55:00			
CMP	C/W NORM - BOOST	2	Inhibits master alarm light on panel 1.

STA/T	STEP	PROCEDURE	PANEL	REMARKS
	4.2.2.6	Pad Abort Enable		
		WARNING After pad abort enbl, oper of THC - CCW will init an abort.		
-44:00				
CDR		EDS PWR - on (up)	7	
CMP		Gear box sel - LATCH	Side hatch	
		Actr handle sel - U (unlatch) (verify)		
ALL		Shoulder harness - locked		
CDR		CM RCS LOGIC - on (up)	1	
		cb SECS ARM (2) - close	8	
		cb SECS LOGIC (2) - close		
		SECS LOGIC (both) - on (up)		Lever lock.
		Report logic arm		
		After GO from STC SECS PYRO ARM (2) - on (up)		Both lever lock pyro arm switches must be operated. LES pad abort capability enabled; SECS LOGIC and PYRO buses are armed.
-28:00				
CMP		H2 FANS (both) - off (ctr)	2	
		O2 FANS (both) - off (ctr)		

Now the SM RCS is activated, please note that most of the RCS displays and controls are not working yet.

Time	Procedure	Panel	Remarks
-00:25:00	*SM RCS activation* SM RCS HELIUM 1 (4) - OPEN SM RCS HELIUM 1 tb (4) - gray SM RCS HELIUM 2 (4) - OPEN SM RCS HELIUM 2 tb (4) - gray SM RCS PROPELLANT (4) - OPEN SM RCS PRIM PRPLNT tb (4) - gray SM RCS SEC PRPLNT tb (4) - gray	2	

This are the last checklist actions before lift-off. Please note that all DSKY interaction mentioned in the original documentation can only be done if you're using the Virtual AGC.

STA/T	STEP	PROCEDURE	PANEL	REMARKS
		4.2.3 LAUNCH PREPARATION		
-20:00				
CMP		Change launch azimuth (if necessary)		
		Key V78E	2	
		FL V06 N29		
		X SM launch azimuth XXX.XX DEG		
		Key V21E, load new azimuth		
		PRO		
		Align GDC to IMU, 4.7.3		Ensures that GDC is aligned to actual IMU angles, rather than calculated values. Attitude reference comparison (in orbit) will be more accurate.
CDR		FDAI SEL - 1	1	
		FDAI SOURCE - ATT SET		Constraint: If CMC is on, an overload in IMU resolver circuitry may cause an ICDU oscillation and trigger ISS warning light. (Reference ICD MH01-01325-216.) FDAI must be used as a null meter in this mode of operation. If not, large errors will result because of impedance mismatch.
		ATT SET - IMU		
		ATT SET tw (3) - null FDAI 1 err		
		ATT SET - GDC		
		GDC ALIGN pb - push		
		FDAI SOURCE - CMC		
		FDAI SEL - 1/2		
		AUTO RCS A/C ROLL (4) - OFF (verify)	8	
		AUTO RCS B/D ROLL B1 & B2 - MNA		
		AUTO RCS B/D ROLL D1 & D2 - MNB		
		AUTO RCS PITCH A3 & C4 - MNB		
		AUTO RCS PITCH C3 & A4 - MNA		
		AUTO RCS YAW B3 & D4 - MNA		
		AUTO RCS YAW D3 & B4 - MNB		

STA/T	STEP	PROCEDURE	PANEL	REMARKS
LMP		BAT C voltage - ___vdc	3	
		DC IND sel - MNA		
CDR		FDAI 1 - total att	1	FDAI 2 is drifting as function of earth rate.
		R ___°, P __.°, Y __.°		
		RMAG MODE (3) - RATE 1		This position provides most reliable configuration in event a rate gyro fails during boost.
		FDAI SCALE - 5/5		Roll attitude error is scaled in PTI assuming FDAI is in 50/15/50/10 position. Until this position is selected at +01:50, roll full scale deflection will be 20°, not 5° as position indicates.
		RATE - HI		
		RHC (both) - ANRCD		
		RHC PWR DIR (both) - MNA/MNB		
		CMC MODE - FREE		
		THC PWR - on (up)		
LMP		S BD - OFF	6	
CDR		VHF AM - OFF	9	
ALL		Perform air-to-ground voice check with MCC-H		
LMP		S BD - T/R	6	
CDR		VHF AM - T/R	9	
		SPS THRUST - MDHI	1	Lever lock.
		AV THRUST (2) - OFF		Guarded.
		α/Pc IND sw - α		
CMP		EDS AUTO - on (up)	2	
		LV RATES sw - AUTO		
		2 ENG OUT sw - AUTO		
		RCS CMD - OFF		OFF position is momentary.
CDR		TVC SERVO PWR 1 - AC1/MNA	7	
		TVC SERVO PWR 2 - AC2/MNB		
-10:00				
LMP		PC REAC VLVS - LATCH	3	

STA/T	STEP	PROCEDURE	PANEL	REMARKS
-08:30				
CMP		SEC COOL PUMP - off (ctr)	2	Crew option may have been exercised to turn SEC COOL PUMP on for crew comfort.
-08:00		Sys stat report		
-06:00		Sys GO/NO GO for launch		
-04:00				
CDR		LV ENG lts (5) - on	1	Launch vehicle engine lights on T -04:00 minutes.
CMP		PO2 (verify)	2	
		CAUTION Do not press ENTR after keying V75. If ENTR is pressed, G&C sys will receive incorrect liftoff time.		
		key V75		
-03:00				
LMP		TAPE RCDR FWD - FWD	3	
		TAPE MOTION tb - gray		Gray display indicates tape is in motion.
-02:15				
CDR		PRIM GLY TO RAD - BYP (pull)	325	Accomplished immediately after GSE water-glycol pump deactivated (T -02:15).
CMP		PRIM GLY DISCH PRESS ind - 37-50 psig PRIM ACCUM QTY ind - 25-50%	2	
-01:15				
LMP		MN BUS TIE (2) - on (up)	5	
-01:00				
CDR,LMP		PAD COMM (2) - OFF	9,6	PAD COMM can be used after launch for intercom backup with PAD COMM VOL thumbwheel decreased.

4.2.3 LAUNCH PREPARATION

STA/T	STEP	PROCEDURE	PANEL	REMARKS
-00:45				
AC		GDC ALIGN pb - push, hold	1	
CP		FDAI 2 total att - no motion	2	
AC		GDC ALIGN pb - rel	1	
		READY FOR IGNITION Refer to Appendix A for cabin switch/ control position at vehicle liftoff.		

Launch checklist

At T+00:00:00 the Saturn launches automatically. The following figure shows the historical launch sequence of Apollo 16 as shown in the *Apollo Operations Handbook Block II Spacecraft - Volume 2 Operational procedures reference* (see below). Please note that possibly there are small differences between the checklist times if you fly other missions than Apollo 16. Please note that all DSKY interaction mentioned in the original documentation, especially the part after arriving in orbit, can only be done if you're using the Virtual AGC.

STA/T	STEP	PROCEDURE	PANEL	REMARKS
		4.3 BOOST AND INSERTION		
		4.3.1 BOOST		
-00:09		Ignition		LV engines lights (5) go on at T -4 min when S-IC indicating circuits are armed.
CDR				
-00:01		LV ENG lts (5) - out	1	Indicates all five engines have achieved over 90 percent of rated thrust.
00:00		LIFT OFF lt - on & NO AUTO ABORT lt - out	00:00 ↑ MODE 1A	Additional lift-off cues: Event Timer start Voice communications from MSFN DSKY displays Program 11
		WARNING Do not press LIFT OFF/NO AUTO ABORT pb if LV RATE or any LV ENG lts on.		Manual abort initiation may be required. (Refer to mission rules.)
		Liftoff verified If LIFTOFF lt off - push		Guarded.
		If NO AUTO ABORT lt on - push		Guarded.
CDR, CMP		Verify EVNT TMR ind resets to zero & starts counting up	RATES ±4°/sec P,Y ±20°/sec R ↓	

STA/T	STEP	PROCEDURE	PANEL	REMARKS
			↓	
CDR		EVNT TMR START - START	1	START position is momentary.
CMP		Verify MSN TMR ind resets to zero & starts counting up	2	
		MSN TMR - RSET/START		RSET position is momentary.
		Verify P11 (auto)		
		No P11 - Key ENTR	MODE 1A	V75 inserted in P02 prior to lift-off.
		V06 N62 VI XXXXX. FPS H dot XXXXX. FPS H pad XXXX.X NM		These parameters will be displayed throughout ascent. VI = Inertial velocity. H dot = Altitude rate. H pad = Altitude above pad radius.

STA/T	STEP	PROCEDURE	PANEL	REMARKS
CDR				
+00:12		Roll prog report		
		Pitch prog - report		
+00:30		Roll prog - complete		
CMP				
+00:42		PRPLNT DUMP - RCS CMD	00:42	
		MODE 1B - report	MODE 1B	
CDR				
+00:50		Mon α/Pc ind > to T +02:00	RATES ±4°/sec P,Y ±20°/sec R	1
CMP				
13K' to 15K'		CAB PRESS ind - starts decr		2
		xxxxxxxxxxxxxxxxxxxxxxx		
		If no decr by 25K'	ATT ERROR	
CDR		rh CAB PRESS RELF vlv - DUMP (safety latch off) until	±5° P,Y	325

Relieves high CM-to-atmosphere ΔP. Assuming that cabin pressure at lift-off is 14.47 to 14.87 psia, the cabin pressure relief valve could begin modulating at 13K'.

STA/T	STEP	PROCEDURE	PANEL	REMARKS
CDR		CAB PRESS ind - 8 psia, then NORM (safety latch on)	2	
		If still no decr	MODE 1B	
CMP		CAB PRESS DUMP vlv - open (CCW) until CAB PRESS ind - 8 psia, then close (CW)	Side hatch 2	
		xxxxxxxxxxxxxxxxxxxxxx		
+01:21		MAX Q	100% AOA 5° ROLL error	
CDR				
+01:56		MODE 1C - report (R3 = 16.5 NM)	01:56 MODE 1C	
CMP				
+02:00		EDS AUTO - OFF		
		2 ENG OUT sw - OFF		
		LV RATES sw - OFF		
CDR		α/Pc IND sw - Pc		1
		LV RATE lt disabled as platform failure cue & limits changed to 9.2° in P&Y		
+02:10		Report GO/NO GO for staging		
+02:15		CECO (LV ENG 5 lt - on)		Center engine cutoff.
		LIFT OFF lt - out (CECO +0.6 sec)		

STA/T STEP	PROCEDURE		PANEL	REMARKS
CDR				
+02:42	OECO (LV ENG 1, 2, 3 & 4 lts - on)		1	Outboard engine cutoff.
+02:43	All eng lts - out SII/SIVB staging capability armed (OECO +1.4 sec)			S-IC/SII separation.
	xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx If early SII/SIVB staging			
CMP	req, LV STAGE - on (up)		2	Guarded.
	xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx	MODE 1C		
CDR				
+02:44	LV ENG 1, 2, 3, 4 & 5 lts - on		1	SII engine ignition.
	SII SEP lt - on			SII 2nd plane separation circuitry armed.
+02:45	All eng lts - out			SII engines 65 percent rated thrust.
CMP	GLY EVAP STM AUTO - AUTO GLY EVAP H2O FLOW - AUTO		2	
CDR				
+03:13	SII SEP lt - out		1	SII interstage jettisoned.
CMP				
+03:18	TWR JETT (both) - on (up) (TFF >1+20)	03:16	2	Guarded. On position is momentary.
	TWR JETT & MODE II report	MODE II		
	xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx No tower jett Go to EMER PROCEDURES, 5.3.2.6			
	xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx			

STA/T STEP	PROCEDURE		PANEL	REMARKS
CMP				
+07:00	Report status	MODE II		
+07:42	CECO (LV ENG 5 lt - on)		1	SII center engine cutoff.
LMP				
+08:00	Report status			
CDR				
+09:00	MODE IV report	09:00		
+09:11	OECO (LV ENG 1, 2, 3 & 4 lts - on)	MODE IV		SII outboard engines cutoff.
+09:12	All eng lts - out			SII/SIVB separation.
	xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx If no SII/SIVB staging			
CMP	LV STAGE - on (up)		2	Guarded.
	xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx			
CDR				
+09:13	LV ENG 1 lt - on		1	SIVB ignition.
+09:16	LV ENG 1 lt - out			SIVB thrust to 65 percent.
CMP				
+10:00	Report/confirm COI MODE IV			Coast orbital insertion.
		10:08		
		MODE III		
+11:00	Report status			
	If CMC takeover exercised during thrusting go to backup for SECO			SIVB cutoff must be manually initiated at a TBD time calculated during the boost.
		MODE IV		

STA/T STEP	PROCEDURE	PANEL	REMARKS
CDR			
+11:29	SECO		SIVB engine cutoff (auto).
	LV ENG 1 lt - on	1	
CMP	Begin TB5		Time base 5.
	MODE IV		
	xxxxxxxxxxxxxxxxxxxxxxxxx		
+TBD	If late SECO		
	or LV GUID sw - CMC	2	
	LV STAGE sw - on (up)		Guarded.
	SECO		
CDR	LV ENG 1 lt - on	1	
	Begin TB5		
	If still no SECO		
	MODE III		
	WARNING		
	THC must be returned from CCW position before 3.0 sec or CSM SLA sep will occur.		
	THC - CCW, return within 1 sec		
	SECO		
	LV ENG 1 lt - on		
	Begin TB5		
	xxxxxxxxxxxxxxxxxxxxxxxxx		
+11:39	INSERTION		INSERTION

BOOST

STA/T STEP	PROCEDURE	PANEL	REMARKS
CMP	LV ENG 1 lt - out (SECO +10 sec)	1	
	Rcd from DSKY	2	
	VI XXXXX. FPS		VI = Inertial velocity.
	H dot XXXXX. FPS		H dot = Altitude rate.
	H pad XXXX.X NM		H pad = Altitude above pad radius. V82 should not be selected during P02 or P11 within 5 seconds of liftoff time (this applies to any extended verb which sets bit 1 of flagword 4).
	(R30, Orbital Parameters)		Displays orbital parameters (N44). A meaningful display of N32 and N50 is available only during R30.
	Key V82E		
	FL V16 N44		
	Ha XXXX.X NM		Ha = Apogee altitude.
	Hp XXXX.X NM		Hp = Perigee altitude.
	TFF XXBXX MIN-SEC		TFF = Time of free fall to 49.4 NM (300,000 feet).
	Key N50E		
	Splash err XXXX.X NM		Negative for undershoot, positive for overshoot.
	Hp XXXX.X NM		
	TFF XXBXX MIN-SEC		
	KEY REL		
	FL V16 N44		
	Ha XXXX.X NM		
	Hp XXXX.X NM		
	TFF XXBXX MIN-SEC		If TFF = -59B59, TF perigee is available by keying N32E.
	PRO		

STA/T STEP	PROCEDURE	PANEL	REMARKS
CMP	V06 N62	2	
	VI XXXXX. FPS		
	H dot XXXXX. FPS		
	H pad XXXX.X NM		
	SAFE ORBIT		
	Key V37E 00E		

Please note that the DSKY interaction on the last 2 pages above can only be done if you're using the Virtual AGC. With the NASSP AGC just enter V37 N00E to go to program P00.

Earth Parking Orbit

After SIVB engine cutoff (SECO) the spacecraft is in an almost circular earth orbit, called "Earth Parking Orbit" (EPO). Now the postorbital insertion checks have to be done.

Time	Procedure	Panel	Remarks
00:12:00	*Postorbital insertion checks*		
	EDS PWR - OFF	7	
	MAIN BUS TIE (2) - OFF	5	
	SECS PYRO ARM (2) - SAFE	8	
	SECS LOGIC (both) - OFF		
	cb SECS ARM (2) - open		
	TRANS CONT PWR - OFF	1	
	ROT CONTR PWR DIRECT (2) - OFF		
	BMAG MODE (3) - RATE 2		
	LV STAGE sw - OFF (verify)	2	
	DIRECT O_2 vlv - CLOSE	7	
	C/W NORM - NORM	2	
	FC REACS VLVS - NORM	3	
	H_2 PURGE LINE HTR - ON		Prepares the FC purge check.
	SM RCS monitoring check		
	SM RCS PRPLNT tb (8) - gray	2	
	SM RCS HELIUM 1/2 tb (8) - gray		
	C&WS operational check		
	C/W OPERATIONAL CHECK C/W LAMP TEST - 1 (LH MA & 15 lts) C/W LAMP TEST - 2 (RH MA & 20 lts) C/W CSM - CM (CM RCS lt (2) - on) C/W CSM - CSM (CM RCS lt (2) - out)	2	CM RCS lights not working yet.
	A more detailed check can be found in the "Internal systems" section.		
	ECS post insertion config		
	PRIM GLY EVAP STM PRESS ind - 0.09-0.14 psi	2	
	PRIM ACCUM QTY ind - 25-50 %		
	RAD FLOW CONT PWR - PWR		
	PRIM GLY TO RAD vlv - NORMAL (push)	325	
	RAD PRIM HTR - 1	2	
	ECS RAD tb - gray		

	GLY EVAP TEMP IN - AUTO POT H_2O HTR - MNA		
	CAB FAN (both) - on (up) O_2 FLOW ind - 1.0 lb/hr O_2 FLOW HI lt - on MASTER ALARM pb/lt - on, push O_2 FLOW HI lt - off PRIM GLY EVAP OUT TEMP ind - 38-43 °F RAD PRIM OUT TEMP ind - below RAD PRIM IN TEMP ind	2 1 2	After a few minutes. After a few minutes.
	Fuel cell purge check FC PURGE CHECK H2/02 PURGE (6) - ON (monitor) Observe Flow rate inc Reset MA (as req'd) H2 PURGE LINE HTR - OFF	3	
	EPS monitoring check EPS MONITORING CHECK Cryogenic Pressure - Quantity Check H2 PRESS (3) - 225-260 psia 02 PRESS (3) - 865-935 psia SURGE TK PRESS - 865-935 psia CRYO FANS - OFF; ON as req'd FC Power Plant Check FC HTRS(3) - on(up) FC RAD tb (3) - gray FC REAC tb (3) - gray FC IND sel - 1, 2, 3 H2 FLOW - 0.03-0.15 lb/hr 02 FLOW - 0.25-1.2 lb/hr MOD SKIN TEMP - 390-440° F MOD COND EXH TEMP - 150-175° F FC pH HI tb - gray FC RAD TEMP LO tb - gray D-C Voltage-Amperage Check MN BUS TIE (2) - OFF (verify) FC MNA tb - 1 & 2 gray, 3 bp FC MNB tb - 1 & 2 bp, 3 gray FC 1, 2, & 3 (check amps) MAIN BUS A, B, (26.5-31 vdc) BAT BUS A, B, & BAT C (31.5-38 vdc < 3 amp) PYRO BAT A, B (36.5 - 37.5 vdc) DC IND sel - MNB SYS TEST 5B (BAT RLY BUS - 3.4-4.1 vdc) A-C VOLTS - 113 to 117 all phases A similar check can be found in the "Internal systems" section.		
	ECS monitoring check		

```
ECS MONITORING CHECK
  SUIT COMP ΔP - .3-.4 psid
  O2 SURGE TANK PRESS - 865-935 psia
  REPRESS O2 >865 psia
  PRIM RAD tb - gray
      *If PRIM RAD tb - 2                *
      *  ECS RAD FLOW AUTO CONT - 1 until*
      *    tb gray, then AUTO            *
  ECS RAD TEMP PRIM IN - 67-97° F
  ECS RAD TEMP PRIM OUT - -20° to +63° F
  PRIM GLY EVAP TEMP OUT - 38-50.5° F
  PRIM GLY DISCH PRESS - 40-52 psig
  SUIT TEMP - 45-55° F
  SUIT PRESS/CABIN PRESS - 4.7-5.3 psia
  PART PRESS CO2 < 7.6 mm Hg
  POT H2O QTY - 10-100%
  WASTE H2O QTY - 25-85%
```

A similar check can be found in the "Internal systems" section.

Secondary water-glycol loop check

```
SECONDARY GLYCOL LOOP CHECK
    ECS IND sw - SEC
    SEC COOL LOOP PUMP - AC1
      GLY DISCH SEC PRESS - 39-51 psig
      ACCUM SEC QTY IND - 30-55%
    SEC COOL LOOP - EVAP
    After 5 min:
      SEC EVAP TEMP OUT - 38-50.5°F
    SEC COOL LOOP EVAP - RSET 1 min,
                         off (ctr)
    SEC COOL LOOP PUMP - off (ctr)
    ECS IND sw - PRIM
```

SCS attitude reference check

This procedure only works with the Virtual AGC.

DSKY 1

```
SCS ATT Ref Comp Check
  V16 N20E
  FDAI SELECT - 1
  FDAI SOURCE - ATT SET
  ATT SET - GDC
  ATT SET dials - null FDAI 1 err needles
  Key VERB when nulled (freeze display)
  Record from DSKY:
  R_______, P_______, Y_______
  Record from ATT SET dials:
  R_______, P_______, Y_______
  FDAI SEL - 1/2
```

Extend docking probe

8 2

```
EXTEND DOCKING PROBE
  cb DOCK PROBE (2) - close (verify)
  DOCK PROBE EXTD/REL - EXTD/REL until
    full probe extension
  (DOCK PROBE tb - gray at full extension)

  DOCK PROBE EXTD/REL - RETRACT (tb-gray)
```

Trans Lunar Injection (TLI) checklist

The next step on our journey to the moon is the Trans Lunar Injection, also called TLI. With a single burn of the SIVB engine we'll escape the EPO and extend our orbit so that we reach the moon. In real Apollo this burn was calculated by mission control. The burn data were uploaded to the Saturn Instrument Unit (IU) and the Apollo Guidance Computer (AGC). In Project Apollo there is no mission control simulation yet, so we have to do that a different way, by using the Orbiter MFDs.

At first the burn data have to be calculated. "Burn data" mean the time when the burn will happen and the velocity difference the burn will cause. The exact values you need is the time to ejection in seconds and the delta velocity in m/s. After that the burn data will be entered in the DSKY and then the AGC will do the burn automatically. There are three Orbiter MFDs capable to do the burn data calculation:

- The build-in **Transfer MFD**
  Use it as explained in the Orbiter user's manual. It's probably the easiest way to do it, but it's also not very accurate.
- The build-in **TransX MFD**
  One of the best tutorials explaining how to use the TransX MFD for the TLI burn is still the NASSP 5.2 tutorial made by SaturnV. It's available here, read the "2. Translunar injection" section: http://nassp.sf.net/download/OrbiterApollo11Tutorial.pdf
- Jarmo Nikkanen's **Interplanetary MFD (IMFD) 4.2.1**
  It's available here: http://koti.mbnet.fi/jarmonik/Orbiter.html. This is probably the most accurate and pursuable way to calculate the burn, because it has a quite precise trajectory prediction. Thanks to Jarmo there's a very good tutorial how to setup an Apollo TLI burn available here: http://koti.mbnet.fi/jarmonik/TLI-FreeReturn.zip and we suggest to use it.

The TLI burn was done in the 2nd orbit after earth orbit insertation, please keep that in mind when setting up the burn. So the time to ejection normally should be roughly about 2h 30min or 9000s, if you do the calculation directly after earth orbit insertation.

After you managed to see the (decreasing) time to ejection (not the time to burn, the AGC does that by itself) and the delta velocity in on of these MFDs, wait until the time to burn is about 30min or 1800s, then you can continue a little bit more historically correct:

Time	Procedure	Panel	Remarks
about 02:00:00	*TLI preparation* cb SECS ARM (2) - close SECS LOGIC (both) - on (up) SECS PYRO ARM (2) - on (up) XLUNAR INJECT - INJECT (verify) Set Digital Event Timer (DET) to 51:00, stopped	 8 2 1	
	Start program P15 Key V37 N15E F 06 33 V22E +00020 (Wait until time to burn is exactly 20min or 1200s) PRO F 06 14 V21E Enter delta velocity in the format +XXXXX PRO	 2	Start P15 "TLI initiate/cutoff ". Set time to burn to 20min For example +03150 for 3150 m/s

	F 06 95 V16E 16 95 R1: Time to burn R2: Delta velocity R3: Velocity at engine cutoff		Monitor burn data

The AGC does the TLI burn fully automatically. You can inhibit the TLI burn sequence by switching the XLUNAR INJECT switch to SAFE until 18s before SIVB ignition, after that you can do this by using the S-II/S-IVB LV STAGE switch (permanent inhibit when used 12s after SIVB ignition or later).

TLI Time	Procedure	Panel	Remarks
	Automatic TLI burn sequence LV GUID - IU (verify) *If LV GUID lt - on: * * LV GUID - CMC * * RHC PWR DIRECT (2) - OFF* TB6 (-09:38): UPLINK ACTY lt - on SII SEP lt - on (TIG-09:38) TB6 + 10sec: UPLINK ACTY lt - out SII SEP lt - out 51:00 (-09:00): Start DET counting up *If LV GUID - CMC: * * V16 N20E * * MNVR to R2 Align = _____(45°)*		
-01:40 -00:18 00:00 00:02 ca. 5 min	DSKY blanks (Ave G on) SII SEP lt - on SII SEP lt - out LV ENG 1 lt - on SIVB ignition LV ENG 1 lt - out LV ENG 1 lt - on SIVB cutoff LV ENG 1 lt - out	2 1	
	SECS PYRO ARM (2) - SAFE PRO F 37 00 ENTR	8 2	 Run program 0, the AGC idling program.

Transposition & Docking checklist

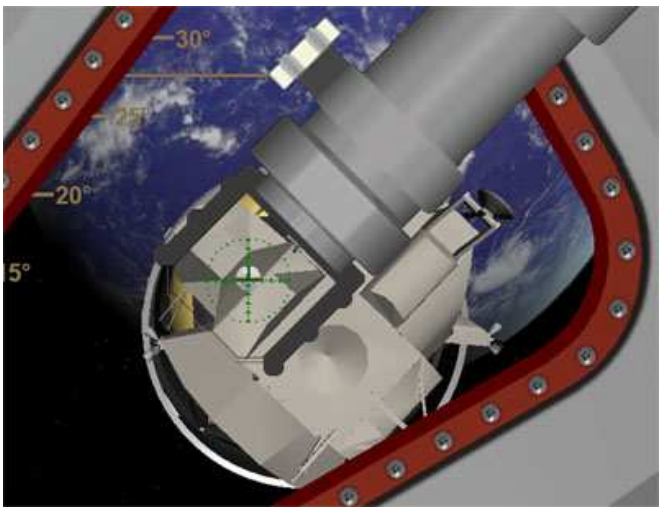
Now we are on the way to the moon, but still connected to the launch vehicle, the SIVB stage. Next we'll separate the CSM from the SIVB, turn around (Transposition), dock with the LM in the SIVB stage and extract it. After that you'll be in the so-called CSM/LM stack flying to the moon, while the remaining SIVB stage will go it's own way.

Time	Procedure	Panel	Remarks
about 03:15:00	*CSM separation preparation* cb DOCK PROBE (2) - close (verify) DOCK PROBE EXTD/REL - RETRACT (verify)	8 2	

	SM RCS PRPLNT tb (8) - gray (verify) Set Digital Event Timer (DET) to 59:30, stopped FC REAC VLVS - LATCH	 1 3	
	CSM separation cb SECS LOGIC (2) - close (verify) cb SECS ARM (2) - close (verify) SECS LOGIC (2) - on (up) (verify) SECS PYRO ARM (2) - ARM Start DET When DET shows 00:00 CSM/LV SEP pb - push, hold and release SM RCS PRPLNT tb (8) - gray (verify) SM RCS HELIUM tb (8) - gray (verify) FC REAC VLVS - NORM	 8 1 2 3	 CSM separation

The CSM is now separated from the SIVB and slowly moving away from it. That's fine, we don't need the SIVB anymore, but it still contains the LM we'll need to land on the moon. So we'll turn round ("Transposition"), dock with the LM, which is no longer covered by the CSM ("Docking"), and then extract the docked LM from the SIVB. This manoever was done manually and so we'll do it.

- Switch to the left rendezvous window panel, use <CTRL><UP> and <CTRL><LEFT> when you look at the main panel. Don't scroll this panel if your screen resolution is too small, otherwise the COAS will not work properly.
- After CSM separation you have full Orbiter-like control over the CSM via it's RCS thrusters, both rotational and translational mode. So switch to rotational and pitch up with about 5°/sec. until you did a 180° turn and look at the SIVB with the LM inside.
- Engage the COAS (the arm with the "reticle") by clicking on it.
- Now you can begin to move towards the LM by using linear thrust and to correct your attitude for docking. You are in correct position when the COAS directly points to the docking target (upside-down "T") on the LM and you don't see the red part of the docking target. This looks like this:



- When you are close enough the CSM docking probe automatically captures the LM (standard

Orbiter docking behavior).

This is the Apollo 15 checklist starting shortly before capture of the LM, the grey lines indicate displays or controls which are not available at the moment, please ignore these steps:

Time	Procedure	Panel	Remarks
	DOCKING Stabilize & align CSM BMAG MODE (3) - ATT 1/RATE 2 At capture: PROBE EXTD/RETR tb-bp (A, pg S/2-14) CMC MODE - FREE Allow probe to damp S/C motions (approx 10 sec) Align Pitch and Yaw with THC (<3°) (minimum possible) DOCK PROBE RETRACT PRIM-1 *If no RETRACT in 30 sec: PRIM-2 * *If still no RETRACT: SEC-1 * After dock latches have engaged: PROBE EXTD/RETR tb - gray (A-1,5,9,;B-3,7,11) SECS PYRO ARM (2) - SAFE SECS LOGIC (2) - OFF EDS PWR - OFF cb EDS (3) - open DOCK PROBE EXTD/REL - OFF DOCK PROBE RETRACT (2) - OFF cb DOCK PROBE (2) - open		

Now you are docked to the LM, which is still attached to the SIVB. The next step is to extract the LM from the SIVB.

Time	Procedure	Panel	Remarks
	Pre LM separation & ejection DET (Digital Event Timer) - RESET cb SECS ARM (2) - close (verify) SECS LOGIC (2) - on (up) SECS PYRO ARM (2) - ARM	 1 8	
	LM separation & ejection SIVB/LM SEP - on (up) Start DET	 2 1	LM separation
	Post LM ejection SECS PYRO ARM (2) - SAFE SECS LOGIC (2) - OFF cb SECS ARM (2) - open	 8	

The CSM/LM stack is now free and slowly moving away from the SIVB, you are on the way to the moon!

Trans Lunar Coast

To be continued...

References

The following documents are used to gather most of the informations needed for the checklists:

- *Apollo Operations Handbook Block II Spacecraft - Volume 1 Spacecraft Description*. SM2A-03-Block II. October 15, 1969. http://history.nasa.gov/afj/aohindex.htm
- *Apollo Operations Handbook Block II Spacecraft - Volume 2 Operational procedures reference*. SM2A-03-Block II-J-(2). July 17, 1970. http://history.nasa.gov/ap16fj/aoh_op_procs.htm
- *Apollo-Soyuz test project. Operations handbook command/service/docking modules (CSM 119/DM 1): Operational procedures reference issue*. July 15, 1974. http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19750004933_1975004933.pdf
- *Apollo 15 CSM Launch Checklist*. July 9, 1971. NASA Manned Spacecraft Center. Houston, Texas. http://www.hq.nasa.gov/office/pao/History/ap15fj/pdf/a15csmlc.pdf
- *Apollo 16 CSM Launch Checklist*. March 7, 1972. NASA Manned Spacecraft Center. Houston, Texas. http://history.nasa.gov/ap16fj/csmlc/csmlc.htm

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