SECTION 4 - CONSUMABLES

Mission profile dependent
3/1/72 Basic

THE SPS ANALYSIS ASSUMPTIONS

FOR THE SPS PROPELLANT ANALYSIS

1. All spacecraft weights and the sequential consumables losses were taken from the Spacecraft Operational Data Book, Amendment 114.

2. The engine I_{sp} assumed for this analysis is 314.9 seconds.

3. The 3σ dispersions are the RSS of the penalties imposed on the SPS margin by 3σ dispersions in propellant loading, mixture ratio, engine I_{sp}, maneuver ΔV, spacecraft weight, and consumable weight losses.

4. The CSM/LM weights for the J-missions have increased to an extent that, for some launch dates, the S-IVB will not have sufficient propellant reserves to compensate for a 3σ engine. Thus, in order to have a combined 3σ confidence level for the S-IVB and SPS, the S-IVB ΔV deficit is covered in the SPS propellant budget.

5. The ground rule for a contingency allowance is to budget for either an LM rescue or for a maneuver to avoid adverse weather conditions at entry, whichever produces the least SPS margin. The ΔV for the LM rescue allowance and the weather avoidance allowance is 600 ft/sec and 300 ft/sec, respectively. For this mission, the weather avoidance allowance produces the least SPS margin.

Mission profile dependent
3/1/72 Basic

APOLLO 16 SPS PROPELLANT SUMMARY

[APRIL 16, 1972, LAUNCH DATE; 72° LAUNCH AZIMUTH]

Item	Required, lb	Remaining, lb
Expected loading		40 796.0
Trapped and unavailable	441.4	40 354.6
Outage	59.8	40 294.8
Unbalance meter	100.0	40 194.8
Available for ΔV		40 194.8
Required for ΔV		
LOI (2807.0 fps)	24 788.4	15 406.4
DOI (206.1 fps)	1 576.6	13 829.8
CIRC (99.6 fps)	396.9	13 432.9
LOPC-1 (158.7 fps)	613.2	12 819.7
LOPC-2 (282.5 fps)	1 064.7	11 755.0
SHAPE (40.0 fps)	160.5	11 594.5
TEI (3212.2 fps)	9 999.2	1 595.3
Nominal remaining		1 595.3
Dispersions		
TLMC (23 fps)	262.2	1 333.1
-3σ performance	363.6	969.5
S-IVB ΔV deficit	0.0	969.5
Margin above 3σ		969.5
Available for contingencies*		969.5

*969.5 lb is equivalent to 365 fps end-of-mission reserve.

3/27/72

4-3

Mission profile dependent

12/7/71 Basic

Ground Rules and Assumptions

1. Following transposition and docking, the S-IVB performs the evasive maneuver.

2. Two midcourse corrections (translunar) are executed as SPS burns with one MCC followed by an RCS trim.

3. One midcourse correction (transearth) is executed as an RCS burn of 5 fps.

4. Quad management is to be determined during the mission.

5. Single jet RCS control during SIM exps.

6. Couple jet RCS control during SIM off periods (major burns).

7. All maneuvering at low rate (0.2°/sec) both docked and undocked.

8. Attitude hold deadband during SIM photography and major burns - 0.5°.

9. Attitude hold deadband at other times - 3.0° (except for 2° deadband test).

10. Lunar orbit usage	SIM photography	1.0 lb/hr
	Rest periods	0.1 lb/hr
	Other	0.5 lb/hr

11. Nominal ullages.

12. Redlines have been defined by the Flight Control Division as an aid in assuring that mission rules are not violated during the mission. They are subject to review during the mission as mission phases are completed and systems capabilities are evaluated. In the event the rescue redline is violated prior to rendezvous, lunar orbit photography activities can be curtailed to conserve propellant. The lunar orbit redline includes a nominal transearth coast phase (with all navigational sightings) plus a 3 sigma G&N TEI cutoff error MCC. If a rescue is required and the lunar orbit redline is violated prior to the nominal TEI, TEI can be performed early and navigational sighting activity curtailed during the transearth phase. The rescue redline is based on the minimized activity during the transearth phase.

3/27/72

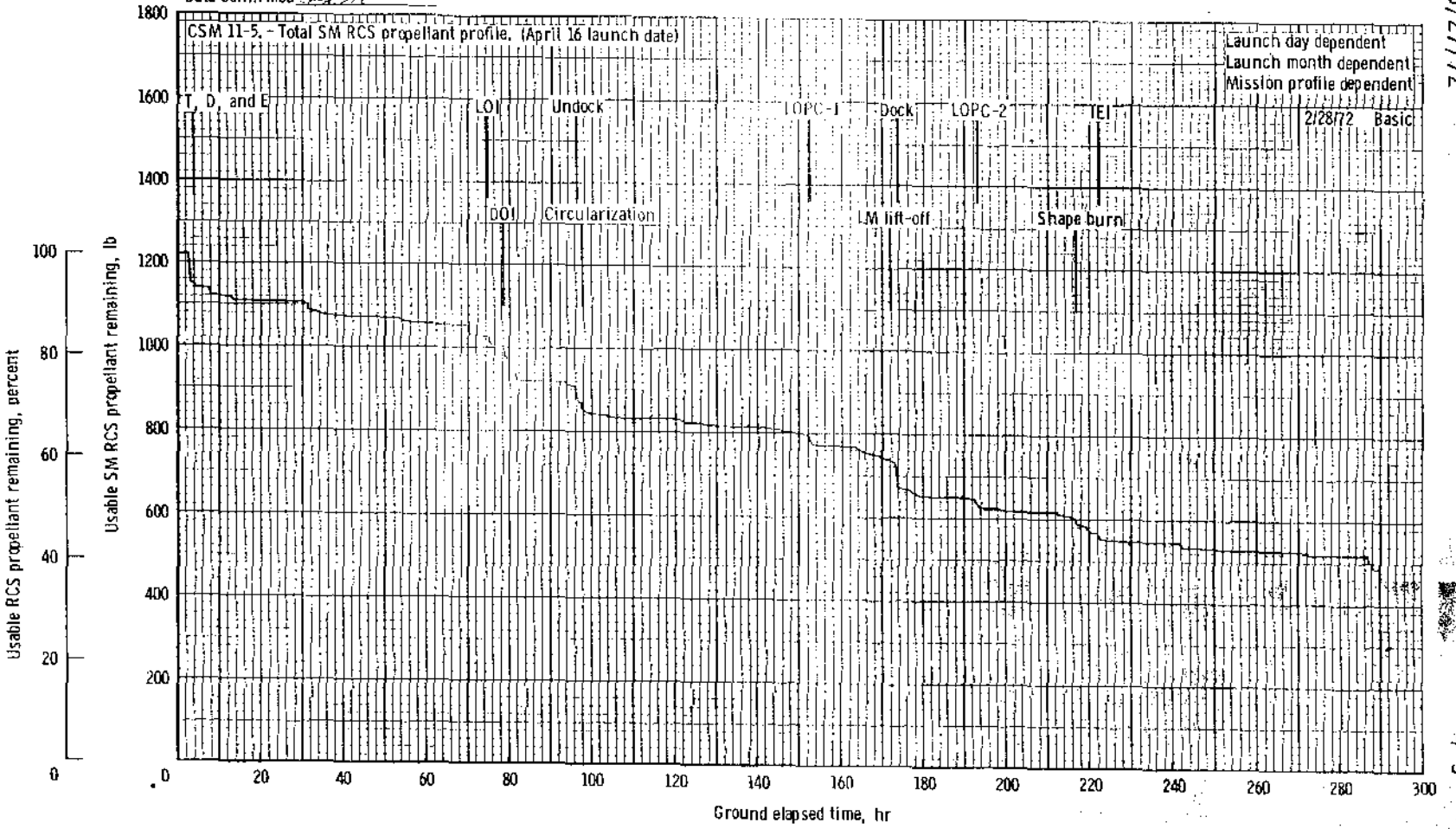
Mission profile dependent
3/1/72 Basic

APOLLO 16 SM RCS ANALYSIS

Item	Required, lb	Remaining, lb
Expected loading	- -	1342.4
Initial outage M/R	15.6	- -
Total trapped	26.4	- -
Gaging inaccuracy*	80.4	- -
Deliverable		1220.0
Nominal usage		
Translunar coast	200	- -
Lunar orbit	468	- -
Transearth coast	92	- -
Total	760	- -
Nominal remaining usable		460.0

*This gaging inaccuracy allows for a 6 percent of total loaded uncertainty. The final consumables analysis will show an increase in deliverable propellant of 22 lb. See Volume I of the SODB for a discussion on gaging inaccuracies.

Mayfield/SMB/MPAD (for Flight Plan, CSM Systems Data)
Data source Flight Plan FCD9
Data confirmed [illegible]

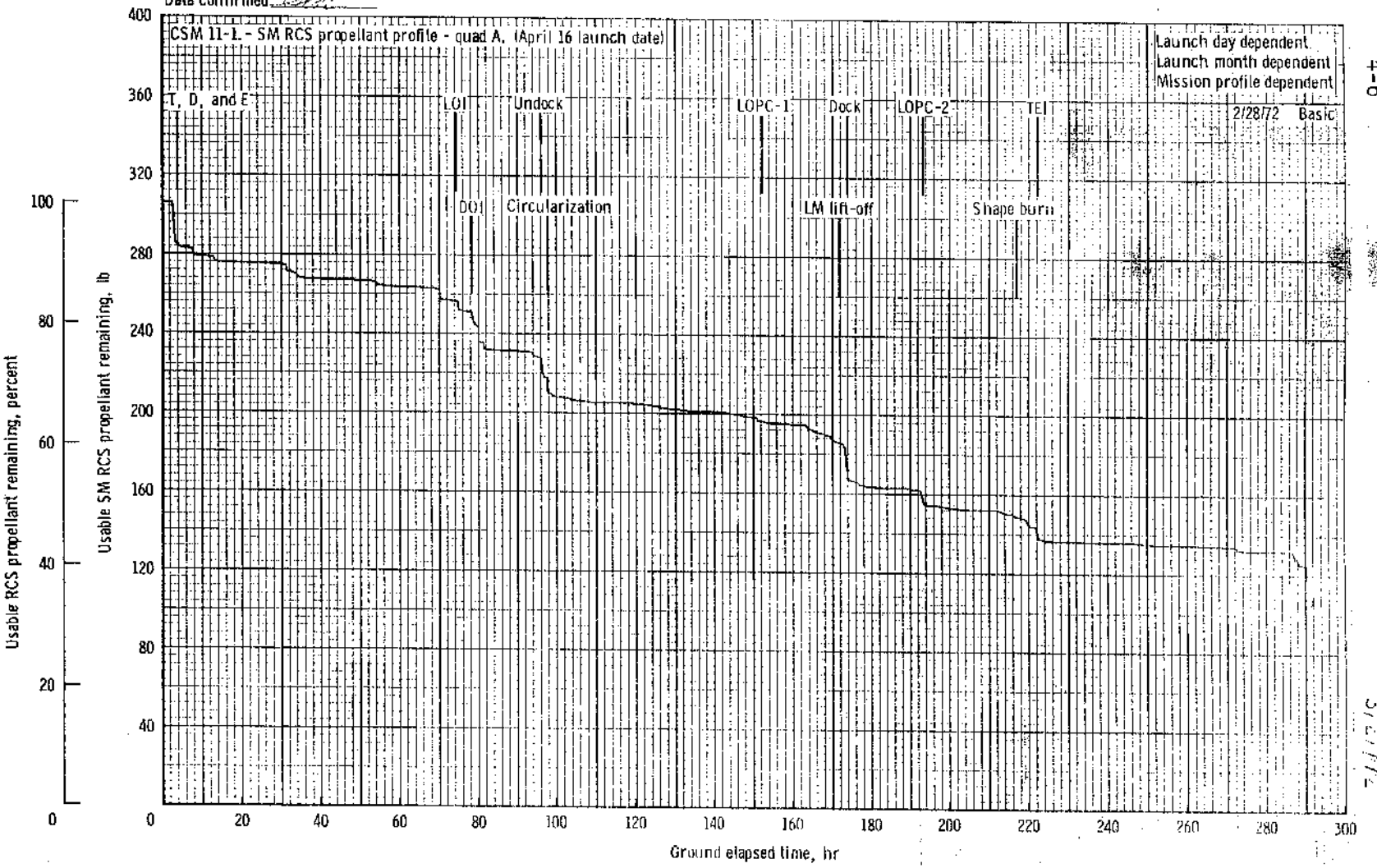


Total SM RCS propellant usage profile.

3/27/72

4-5

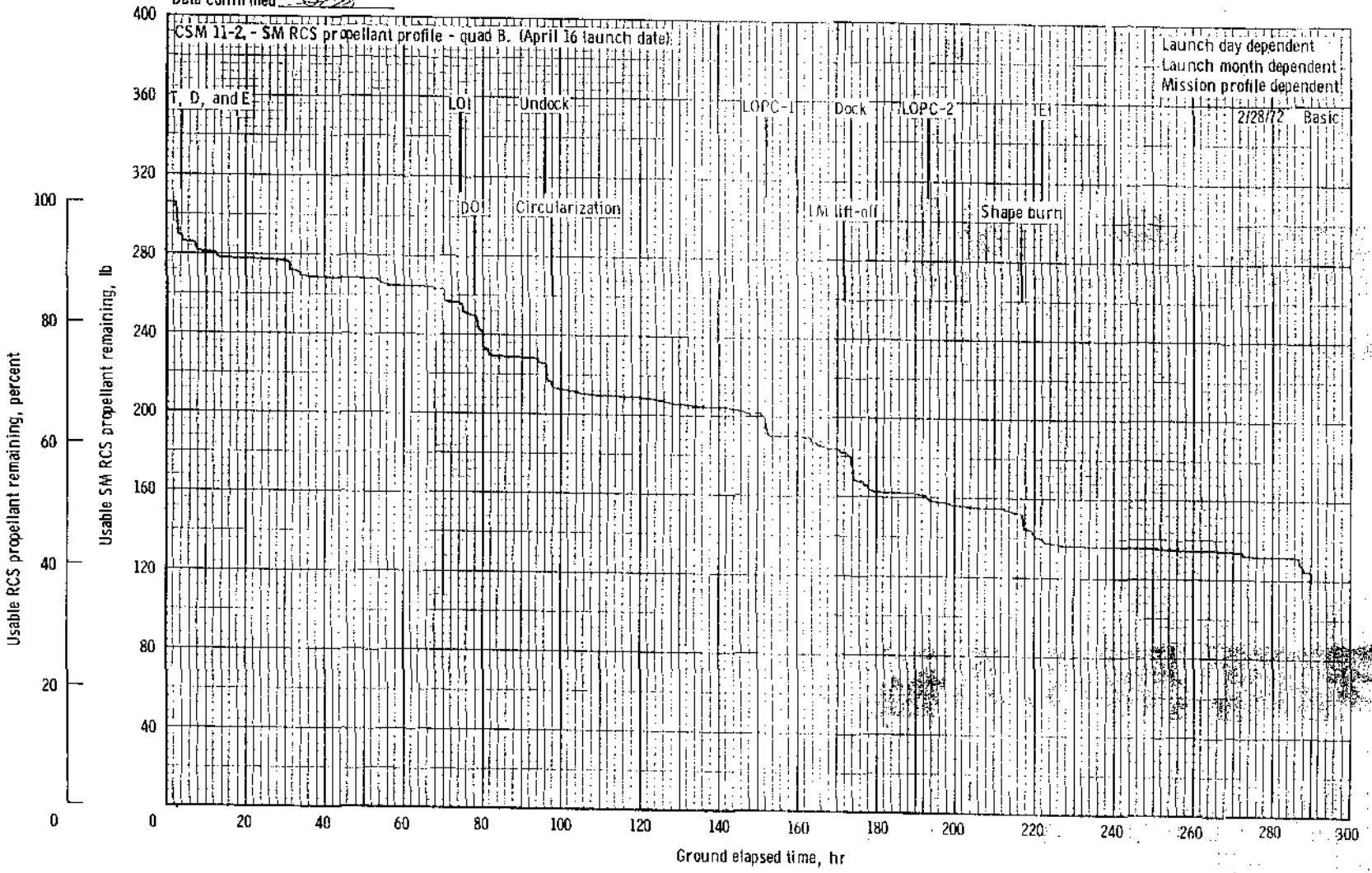
Mayfield/SMB/MPAD (for Flight Plan, CSM Systems Data)
Data source Flight Plan & SCIB
Data confirmed



SM RCS propellant profile - quad A.

3/27/72

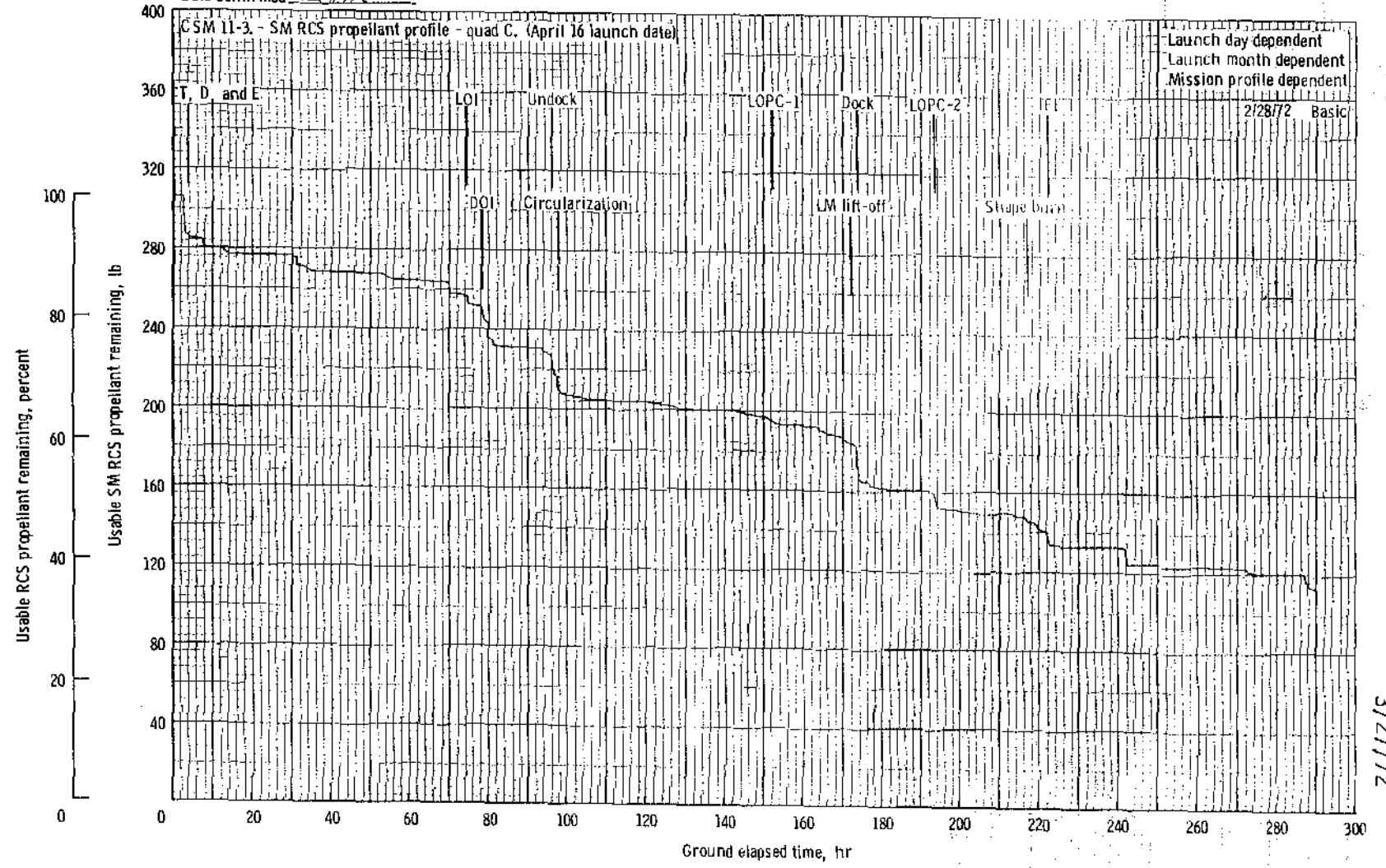
Mayfield/SMB/MPAD (for Flight Plan, CSM Systems Data)
Data source Flight Plan, SCOB
Data confirmed



SM RCS propellant profile - quad B.

3/27/72

Mayfield/SMB/MPAD (for Flight Plan, CSM Systems Data)
Data source Flight Plan, CSM
Data confirmed [illegible]

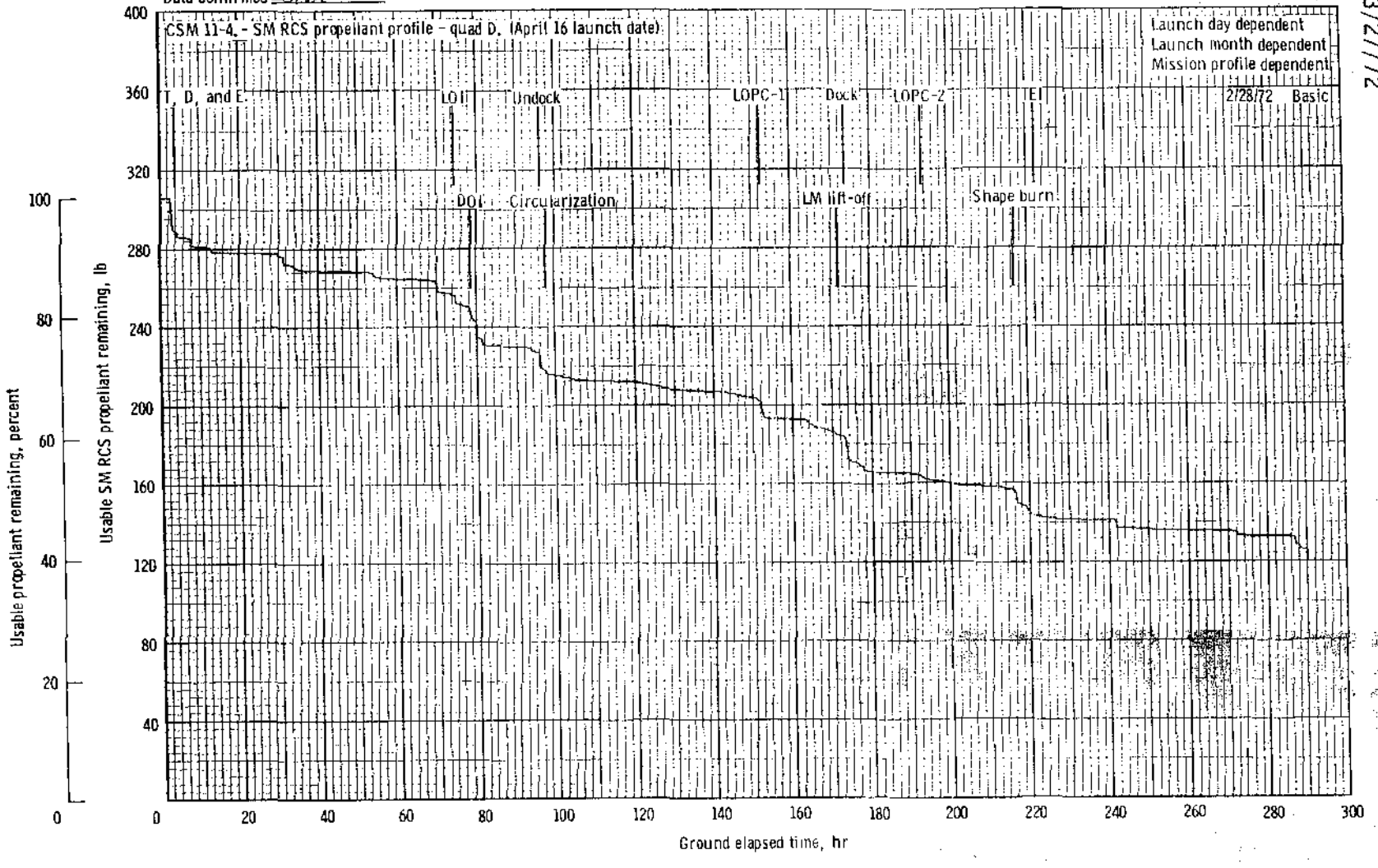


SM RCS propellant profile - quad C.

4-8

3/27/72

Mayfield/SMB/MPAD (for Flight Plan, CSM Systems Data)
Data source: Flight Plan ESDB
Data confirmed: Apollo



SM RCS propellant profile - quad D.

3/27/72

4-9

Mission profile dependent
3/8/72 Basic

CM RCS PROPELLANT SUMMARY

Item	Propellant required, lb	Propellant remaining, lb
Loaded	--	233.2
Trapped	36.4	196.8
Available for mission planning . . .	--	196.8
Nominal usage*	59.3	137.5
Nominal remaining	--	137.5

*CM RCS propellant usage is for dual ring operation with DAP control

Mission profile dependent
12/13/71 Basic

GROUND RULES AND ASSUMPTIONS FOR THE CSM CRYOGENICS

1. Three O_2 and H_2 tanks are available.

2. Fuel cell purging is included in the EPS requirements.

3. No cryogenic venting was assumed in flight.

4. The EPS hydrogen consumption rate $(\dot{H}_2)$ (lb/hr) = 0.00257 × I_{fc} when I_{fc} is the total fuel cell current.

5. The EPS oxygen consumption rate $(\dot{O}_2)$ (lb/hr) = 7.936 × $\dot{H}_2$.

6. No allowance for the SM enhancement battery is assumed.

Mission profile dependent
3/1/72 Basic

7. The following tank depletion schedules are being used:

CRYO MANAGEMENT SCHEDULE

GET (hrs:min)	Tank numbers				
	Oxygen htrs[a]		H_2 tank 1, 2 htrs, tank 3 fan		
	Auto	Off	Auto	Manual	Off
0:00	1, 2	3	1, 2	3	
3:12	1, 2, 3				
4:12	1, 2	3			
14:30	3	1, 2	1, 2, 3		
23:06			3		1, 2
31:30	1, 2, 3				
32:42	3	1, 2			
[a]70:00	1, 2	3	1, 2		3
93:48	3	1,2			
107:24	1, 2	3			
191:30	3	1, 2			
201:30	1, 2	3			
241:54	1, 2, 3				
243:18	1, 2	3			

[a]Switch to 100-watt heaters in O_2 tanks 1, 2, and 3 at this time.

The CSM consumables summary (table 5-I) shows that a significant H_2 and O_2 margin exists at the end of the mission. This is reflected in the H_2 and O_2 usage profiles shown in figures 5-1 and 5-2. However, these curves do not include dispersions.

In summary, the nominal mission requirements can be satisfied with the existent consumables.

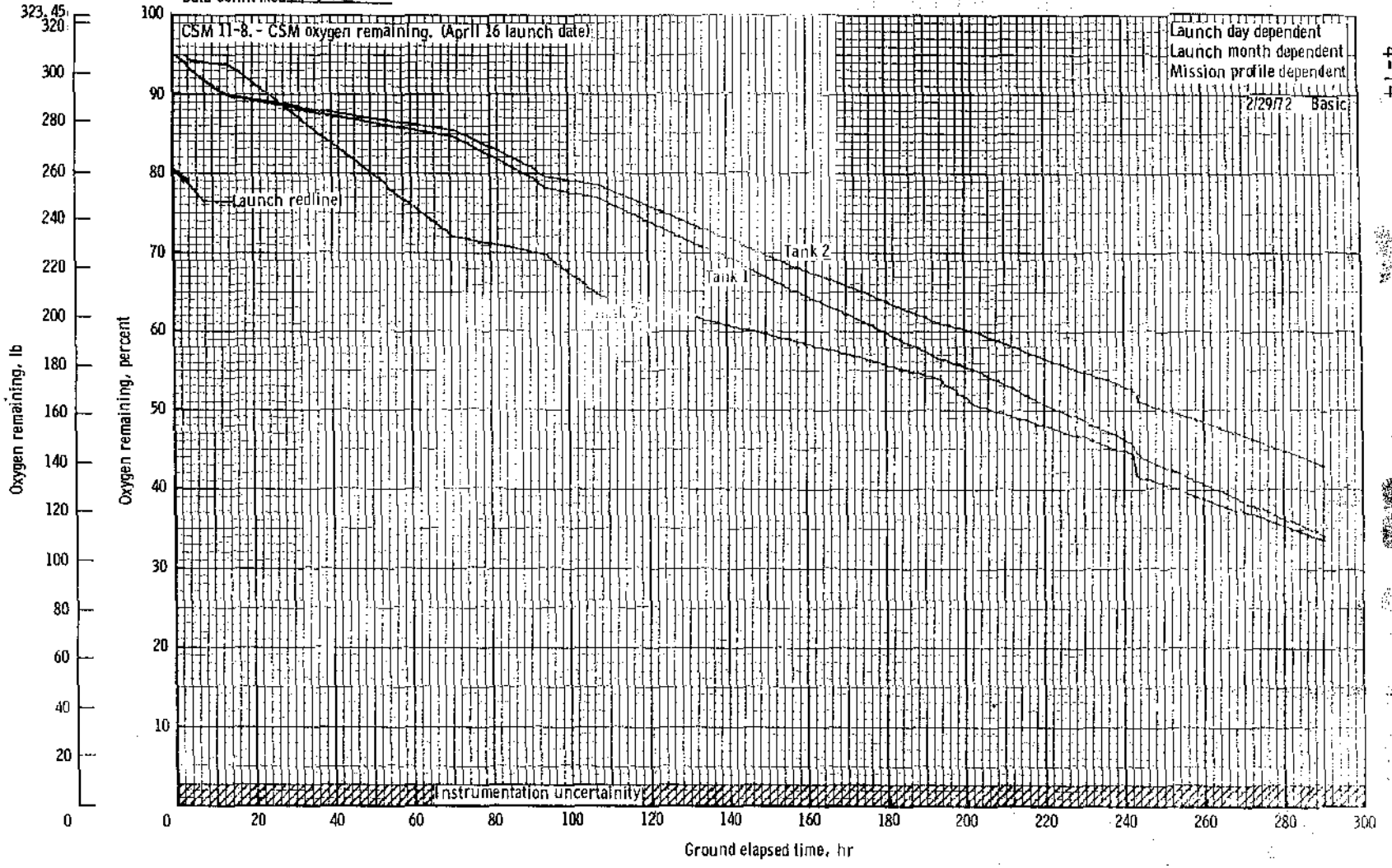
Mission profile dependent
3/1/72 Basic

APOLLO 16 CRYOGENIC SUMMARY

	H_2 lbs	O_2 lbs
PLANNING ALLOWANCE		
TOTAL LOADED	87.9	990.3
LESS RESIDUAL	3.5	19.8
LESS INSTRUMENTATION ERROR	2.3	26.0
AVAILABLE FOR MISSION PLANNING	82.1	944.5
PRELAUNCH REQUIREMENT*	3.8	48.3
FLIGHT REQUIREMENT		
EPS (INCLUDING FUEL CELL PURGE)	59.3	470.9
ECS (INCLUDING CABIN PURGE + EVA)	--	83.7
LM PRESSURIZATION	--	11.1
	59.3	565.7
NOMINAL RESERVES		
EPS UNCERTAINTY (2.5%)	1.5	11.8
ECS UNCERTAINTY (.08 #/HR)	--	23.2
	1.5	35.0
TOTAL REQUIREMENT	64.6	649.0
MARGIN T = 0 (FILL/LAUNCH)	17.5	295.5

*Supplied by KSC.

Cantin/SMB/MPAD (for Flight Plan)
Data source SODB, 7 OF Pln
Data confirmed P. J. C.

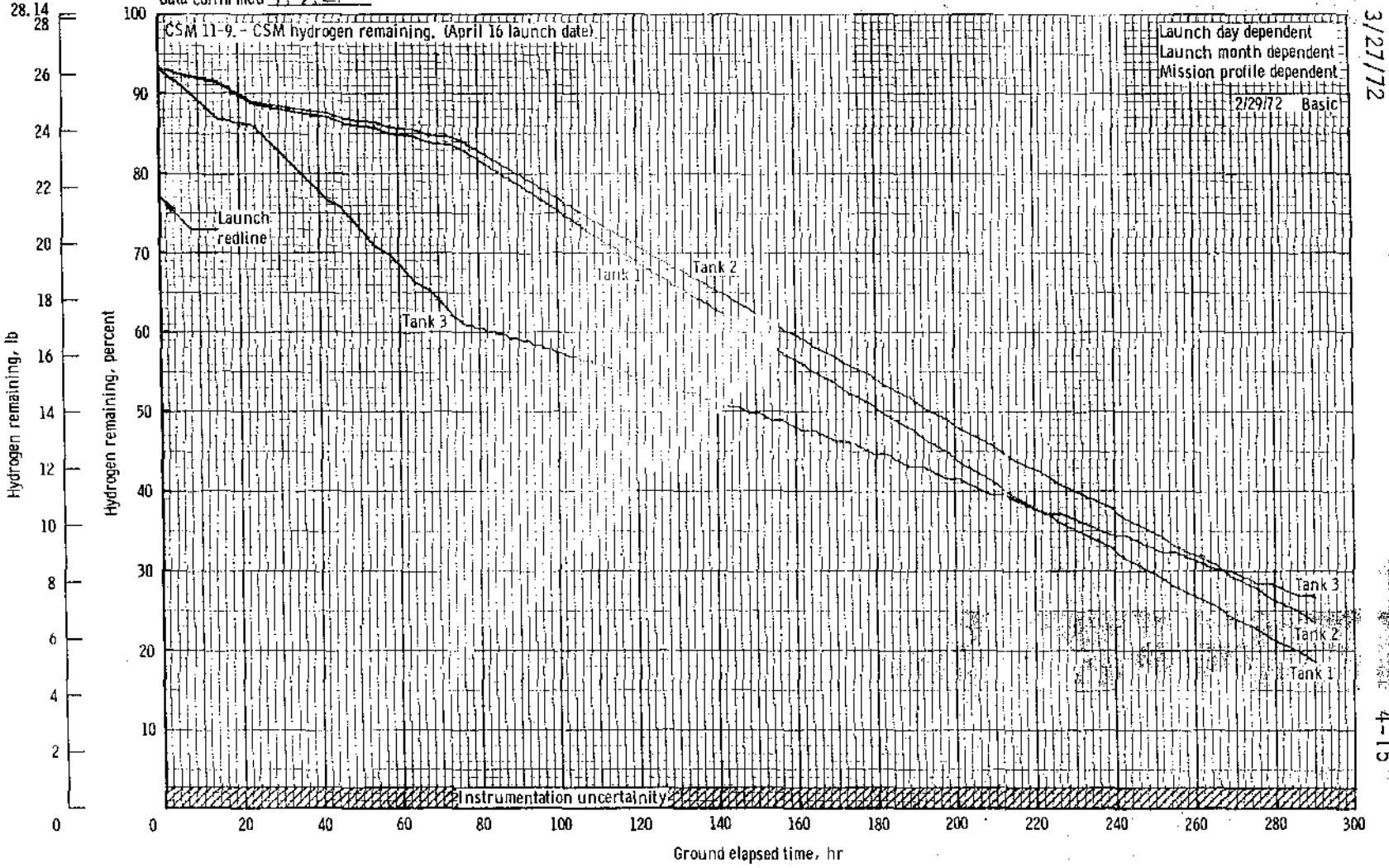


CSM oxygen remaining.

4-14

3/27/72

Cantin/SMB/MPAD (for Flight Plan)
Data source SODB 7 ft. Plan
Data confirmed B.T.C.



CSM hydrogen remaining.

3/27/72

Mission profile dependent
3/1/72 Basic

ASSUMPTIONS FOR THE DPS ANALYSIS

The propellant loading is based on the optimization of the fuel and oxidizer balance that was computed from the LM-11 engine data. The ΔV requirements were coordinated with the Landing Analysis Branch. The ΔV requirement for lunar descent differs from that in the operational trajectory because of differences in the inert vehicle weight.

The 3σ dispersions represent total propellant cost based on 3σ uncertainties in propellant loading, trapped propellant, specific impulse, ΔV, separation weight, non-ΔV consumables weight, mixture ratio, and physical location of the low level sensor.

A flying time of 2 minutes and 30 seconds below low gate will be called a nominal requirement.

The following data were used:

a. The separation weight is 36 624.4 $\pm$ 39.3 pounds.

b. Integrated average I_{sp} is 305.9 $\pm$ 1.8 seconds.

c. Mixture ratio is 1.595 $\pm$ .012.

d. Non-ΔV consumables from separation to PDI are 90.5 pounds.

Mission profile dependent
3/1/72 Basic

DPS PROPELLANT SUMMARY

Item	Total propellant, lb	Hover time, sec
Loaded	19 559.1	--
Trapped and unavailable	-124.7	--
Outage	-16.6	--
Available for ΔV	19 417.8	--
Required for ΔV (150-sec flying time from low gate, ΔV = 7057.7 fps)	-18 726.1	--
Remaining	691.6	74
Dispersion (-3σ)	-278.9	--
Pad	412.7	44
Operational allowances		
Low-level (5 sec, 26.5 fps)	-47.3	--
Abort reserve (20 sec, 106 fps)	-187.9	--
Margin (hover time before abort decision point)	180.5	19

3/27/72

Mission profile dependent
3/1/72 Basic

ASSUMPTIONS FOR THE APS ANALYSIS

The propellant loading is based on the optimization of the fuel and oxidizer balance that was computed from the LM-11 engine data. The ΔV requirements were coordinated with the Landing Analysis Branch. The ΔV requirement for the lunar ascent differs from that in the Operational Trajectory because of differences in the inert vehicle weight.

The APS analysis accounts for an APS TPI, engine valve-pair malfunction, and balanced couples. A touchdown abort was not considered because the nominal lift-off weight is heavier than the abort weight. The following data were used.

a. $I_{sp} = 309.5 \pm 3.5$ seconds.

b. Mixture ratio = $1.597 \pm .027$.

c. Lift-off weight = $10\ 892.2 \pm 38.7$ pounds.

Mission profile dependent
3/1/72 Basic

APS PROPELLANT SUMMARY

Item	Total propellant, lb
Loaded	5242.5
Trapped and unavailable	-51.9
Outage	-11.9
Available for ΔV	5178.7
Required for Ascent (6048.1 fps)	-4958.9
Remaining	219.8
Required for APS TPI[a] (52.8 fps)	-31.4
Remaining	188.4
Dispersions (-3σ)	-67.6
Pad	120.8
Operational allowances	
Engine valve-pair malfunction ($\Delta MR = +.01$ or $-.018$)	-20.9
Balanced couples on	-41.4
Half-degree out of plane (18 fps)	-10.7
Margin	47.9

[a]The total TPI ΔV is 74.8 fps. It is assumed that 22 fps is obtained by a 10-sec, 4-jet ullage.

Mission profile dependent
12/7/71 Basic

ASSUMPTIONS AND GROUND RULES FOR THE LM RCS ANALYSIS

1. Data for the LM RCS engine performance and propellant requirements were obtained from the SODB, Volume II, and from postflight analyses of Apollo 9-15 missions.

2. The analysis assumes an insertion trim or RCS tweak burn (nominally zero) of 30 fps.

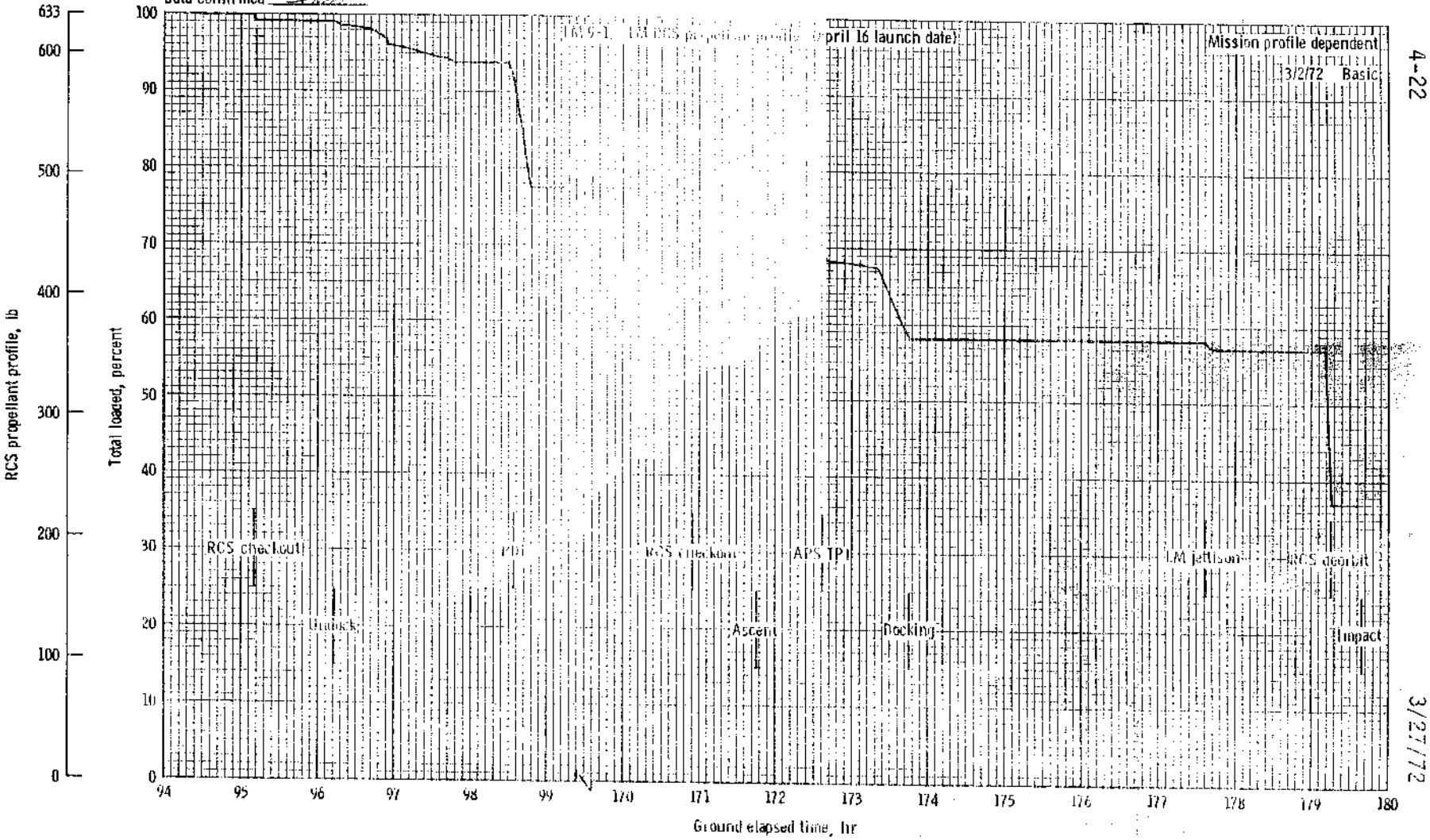
3. It is assumed there will be a 10-fps RCS trim following the APS TPI maneuver.

Mission profile dependent
3/1/72 Basic

LM RCS PROPELLANT LOADING AND USAGE SUMMARY

Item	Required, lb	Remaining, lb
Loaded		631.2
Trapped	38.0	593.2
Gaging inaccuracy and loading tolerance	43.5	549.7
Mixture ratio uncertainty	17.0	532.7
Usable		532.7
Nominal usage through lunar landing	141.6	391.1
Nominal usage from landing through docking	123.7	267.4
Nominal usage from docking through impact	138.7	128.7
Usable propellant remaining		128.7

Mayfield/SMB/MPAD (for LM Systems)
Data source [illegible]
Data confirmed [illegible]



LM RCS propellant profile.

3/27/72

Mission profile dependent
11/24/71 Basic

ASSUMPTIONS FOR THE LM EPS ANALYSIS

a. Energy available from the descent batteries is 2075 A-h and from the ascent batteries is 592 A-h.

b. Energy unusables caused by lack of continuous MSFN coverage for the descent and ascent stages are zero.

c. Energy unusables caused by TM inaccuracies for the descent and ascent stages were 72 and 17 A-h, respectively. The new descent battery current measurement uncertainty of 0.5 amperes per battery was used.

d. Energy unusables caused by checklist deviations (dispersion) for the descent and ascent stages were 33 and 6 A-h, respectively. This dispersion is obtained by calculating 2 percent of the energy used.

e. No energy was budgeted for the PGNCS power uncertainty.

f. In accordance with the Flight Plan, the PGNCS was in standby mode from surface powerdown until 2.83 hours before powerup.

g. The RCS heaters were assumed to have a 100 percent duty cycle for 15 minutes after initial activation and then to decrease to a 7 percent duty cycle until undocking. From undocking until lunar surface powerdown, the heaters were assumed to cycle at 0 percent, but, from surface powerdown until lunar lift-off, the duty cycle was assumed to be 4.5 percent.

h. The MESA heater power requirements were established by GAEC thermal analysis. From circuit breaker activation to touchdown the heater was assumed to be on 35 percent of the time in the low mode (two 25 watt heaters). From touchdown to the start of the open thermal blanket period of EVA-1 the duty cycle was 20 percent in the high mode (six 25 watt heaters). The duty cycle was 55 percent (high mode) during the open blanket period. At the end of the open blanket period the duty cycle decreased to 29 percent. At the start of EVA-2 the MESA heaters were turned off for the remainder of the mission.

i. The invertor was operated throughout the mission.

j. The CDR and LMP forward window heaters were assumed not to be needed.

ASSUMPTIONS FOR THE LM EPS ANALYSIS - Concluded

k. TV power is supplied by the LM during the first hour of EVA-1. For the remainder of EVA-1 and the other EVA's, the TV will be powered by the lunar communications relay unit (LCRU).

l. The liquid cooled garment pump was operated before each EVA for 17 minutes.

m. The S-band power amplifier was cycled as dictated by the time line.

n. The portable utility lights were assumed to be off throughout the mission.

o. In accordance with the Flight Plan, the floodlights were turned off at surface power down, and on again at power up. The overhead and forward floodlights were not used.

p. The short (M=1) rendezvous was considered nominal.

q. At the beginning of the analysis, it was assumed that a total of 10 A-h had been used from the descent batteries between the period starting 30 minutes before launch and ending at the conclusion of transposition and docking.

Mission profile dependent
11/24/71 Basic

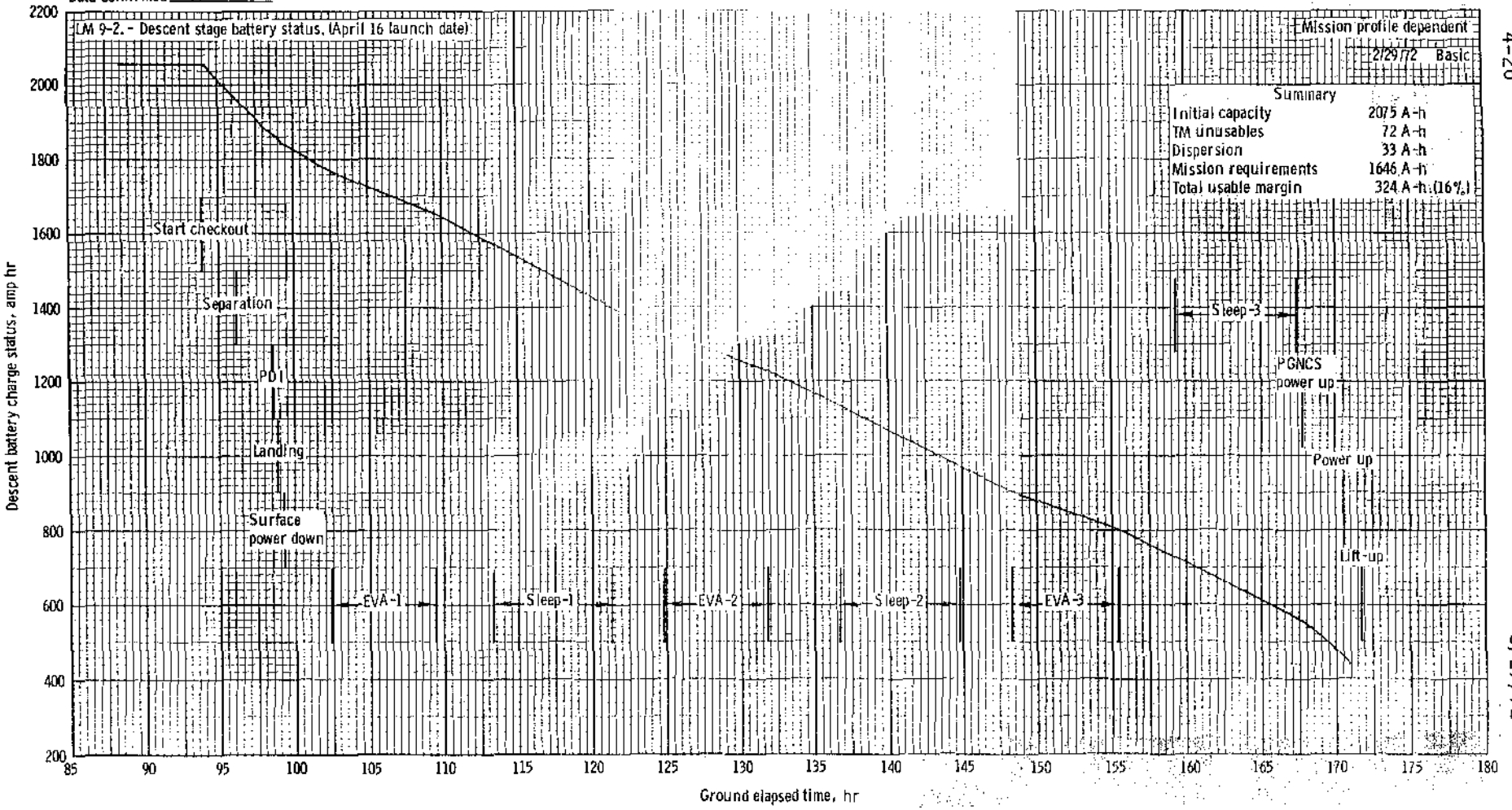
DESCENT STAGE EPS SUMMARY

Item	A-h required	A-h remaining
Initial capacity	--	2075
Total unusables	105	1970
Required through touchdown	214	1756
Required for surface stay	1432	324
Total usable margin	--	324

ASCENT STAGE EPS SUMMARY

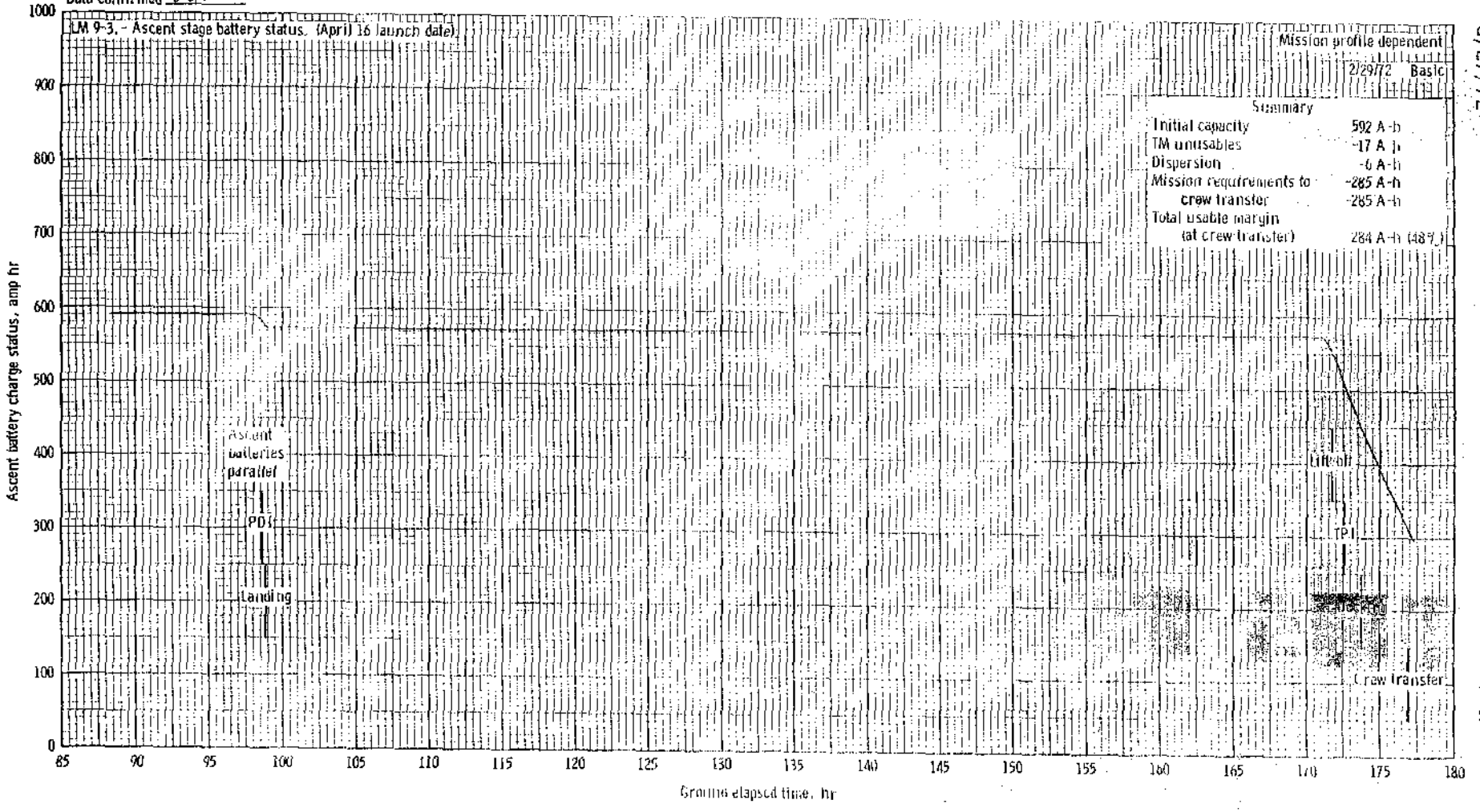
Item	A-h required	A-h remaining
Initial capacity	--	592
Total unusables	23	569
Required through docking	145	424
Required from docking through crew transfer	140	284
Total usable margin	387	284

Ritchey/SMB/MPAD (for LM Systems)
Data source Nelum Flight Plan
Data confirmed JSR



Apollo 16 descent electrical energy remaining.

Ritchey/SMB/MPAD (for LM Systems)
Data source Sudan Flight Plan
Data confirmed USE

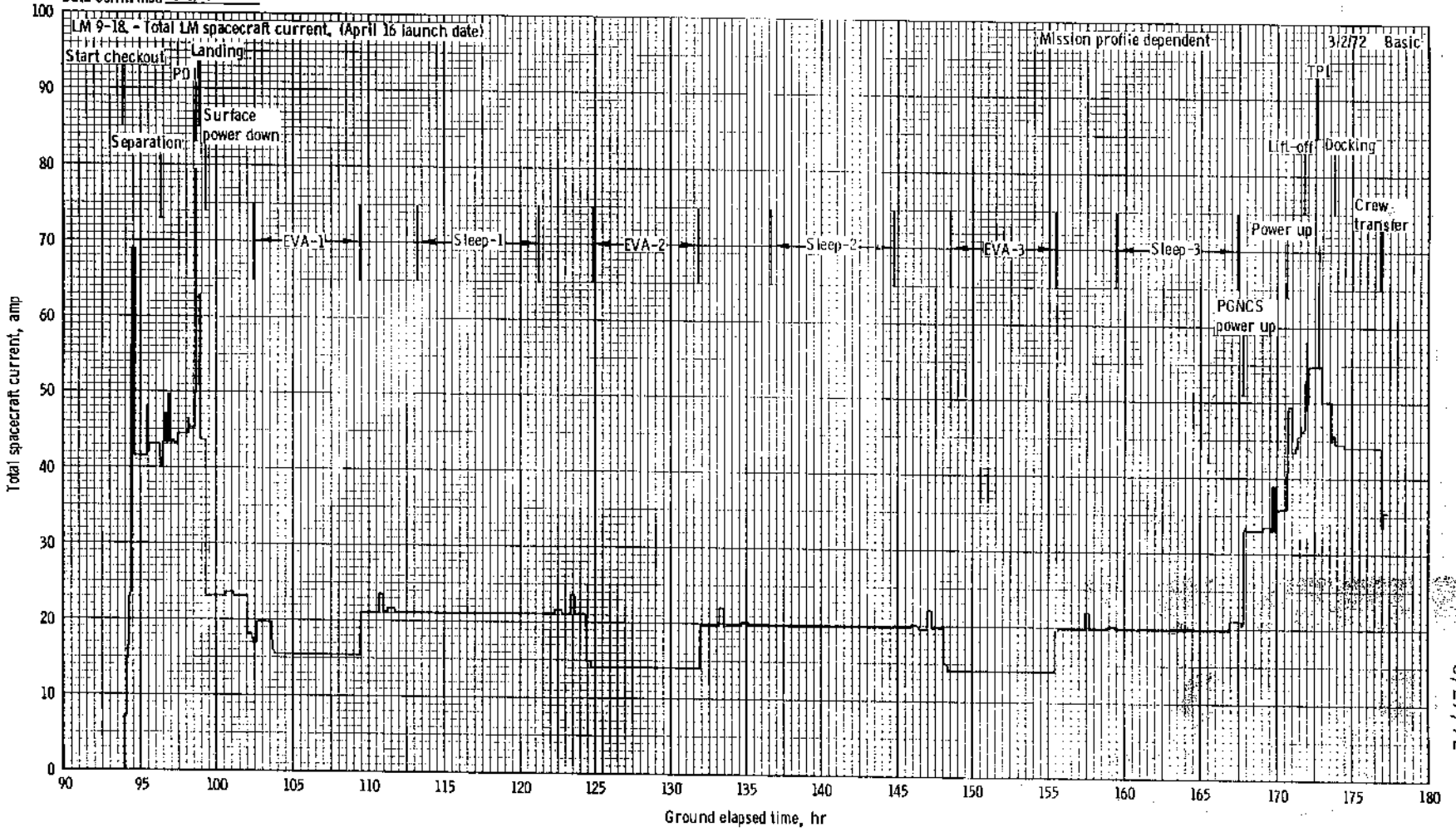


Apollo to ascent electrical energy remaining.

3/27/72

4-27

Ritchey/SMB/MPAD (for LM Systems)
Data source Cislunar Flight Plan
Data confirmed USR



Apollo 16 total LM spacecraft current,

Mission profile dependent
12/7/71 Basic

LM ECS Assumptions

a. The oxygen analyses were calculated using a cabin leak rate of 0.06 lb/hr based on previous Apollo postflight analyses.

b. Metabolic rates were varied using the final flight plan and table 4.3-II of SODB Vol. II.

c. Metabolic oxygen consumed was calculated by
$(1.643 \times 10^{-4} \times$ lb/Btu) (metabolic rate, Btu/hr).

d. The cabin regulator check and the suit integrity check were assumed to require 0.5 pound of oxygen.

e. The cabin was pressurized five times with 5.5 pounds required for each pressurization except the last one which required 5.8 pounds.

f. The dispersion in the oxygen profile was calculated as 5 percent of the nominal oxygen requirement.

g. The PLSS refills required 47.2 pounds of water and 5.4 pounds of oxygen.

h. The sublimator fill required 2.23 pounds.

i. The drink bags required 12.0 pounds of water.

j. Water lost through crew micturition was 0.11 lb/hr per man.

k. Water required for thermal control was calculated by dividing the total spacecraft heat load by 1040 Btu/lb.

l. The dispersion in the water profile was calculated as 5 percent of the nominal usage.

m. The descent oxygen tanks were loaded to 2610.0 psi at 70.0°F.

Mission profile dependent
12/7/71 Basic

LM ECS SUMMARY

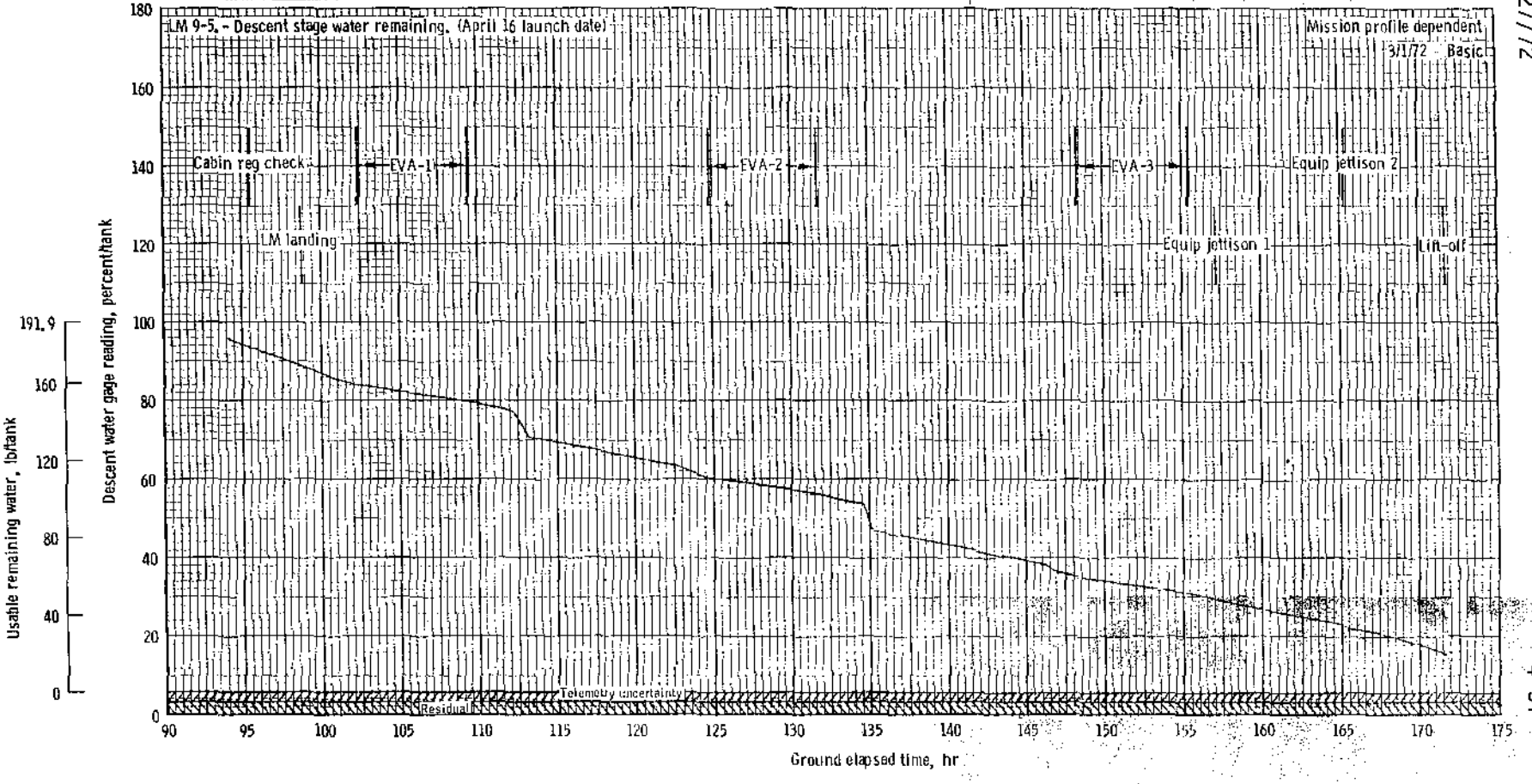
(a) Water

Description	Descent, lb	Ascent, lb
Loaded	406.0	85.0
Sampling	11.0	0
Residual	13.3	1.7
Telemetry uncertainty	8.9	7.5
Loading uncertainty	3.0	1.8
Available for mission	369.8	74.0
Required to lunar landing	32.2	0
Required to lunar lift-off	298.6	0
Required to LM/CSM docking	0	16.4
Required to LM close-out	0	16.2
Required to lunar impact	0	9.6
Remaining in tanks	39.0	31.8
Dispersion	16.5	2.1
Margin	22.5	29.7

(b) Oxygen

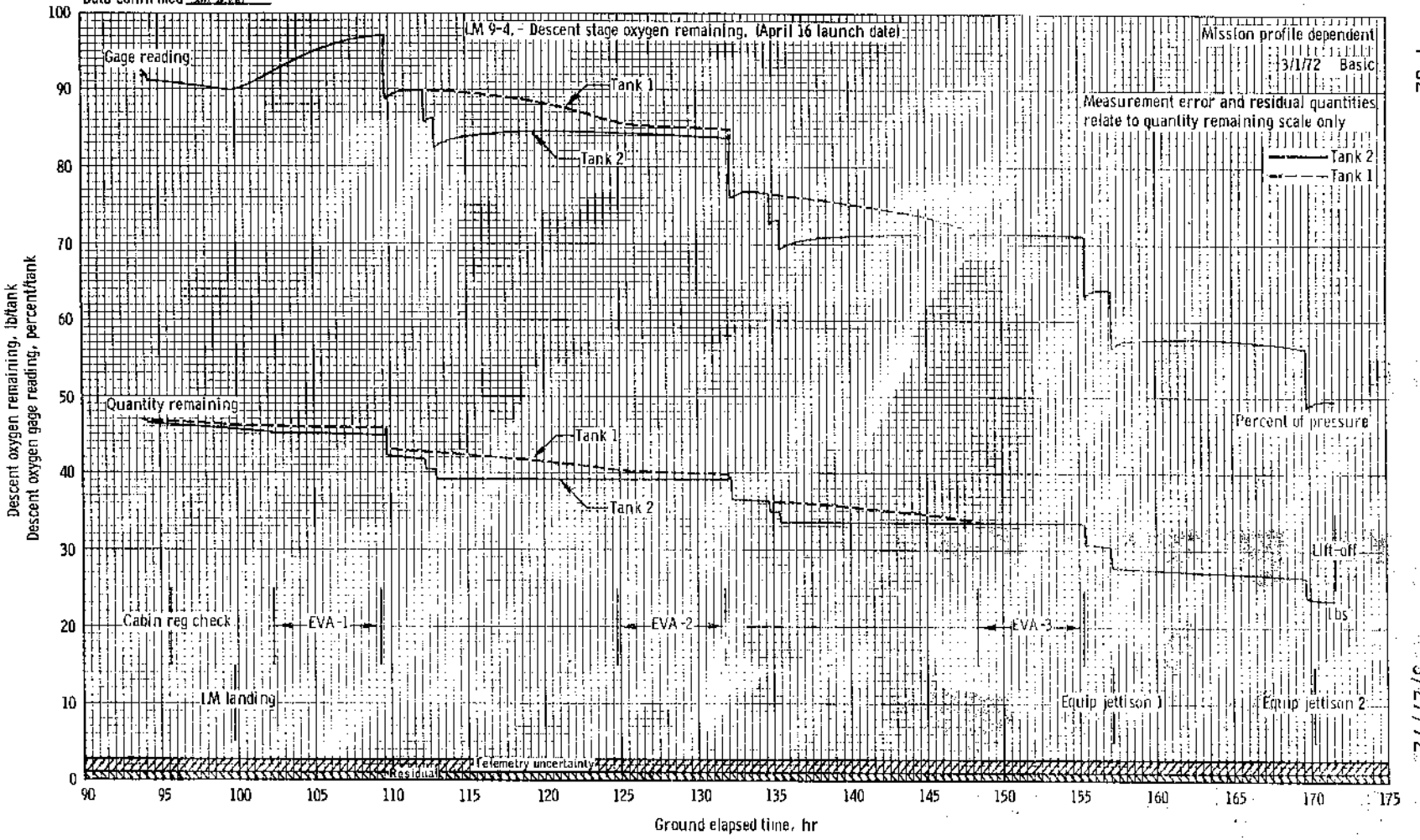
Description	Descent, lb	Ascent 1, lb	Ascent 2, lb
Loaded	93.8	2.4	2.4
Residual	1.6	0.1	0.1
Loading uncertainty	1.7	0.1	0.1
Available for mission	90.5	2.2	2.2
Required to lunar landing	1.7	0	0
Required to lunar lift-off	45.1	0	0
Required to LM/CSM docking	0	0.5	0
Required to LM close-out	0	0.1	0
Remaining in tank	43.7	1.6	2.2
Dispersion	2.3	0.1	0
Margin	41.4	1.5	2.2

Swalin/SMB/MPAD (for LM Systems)
Data source Flight Plan & Spec
Data confirmed Don Puddy



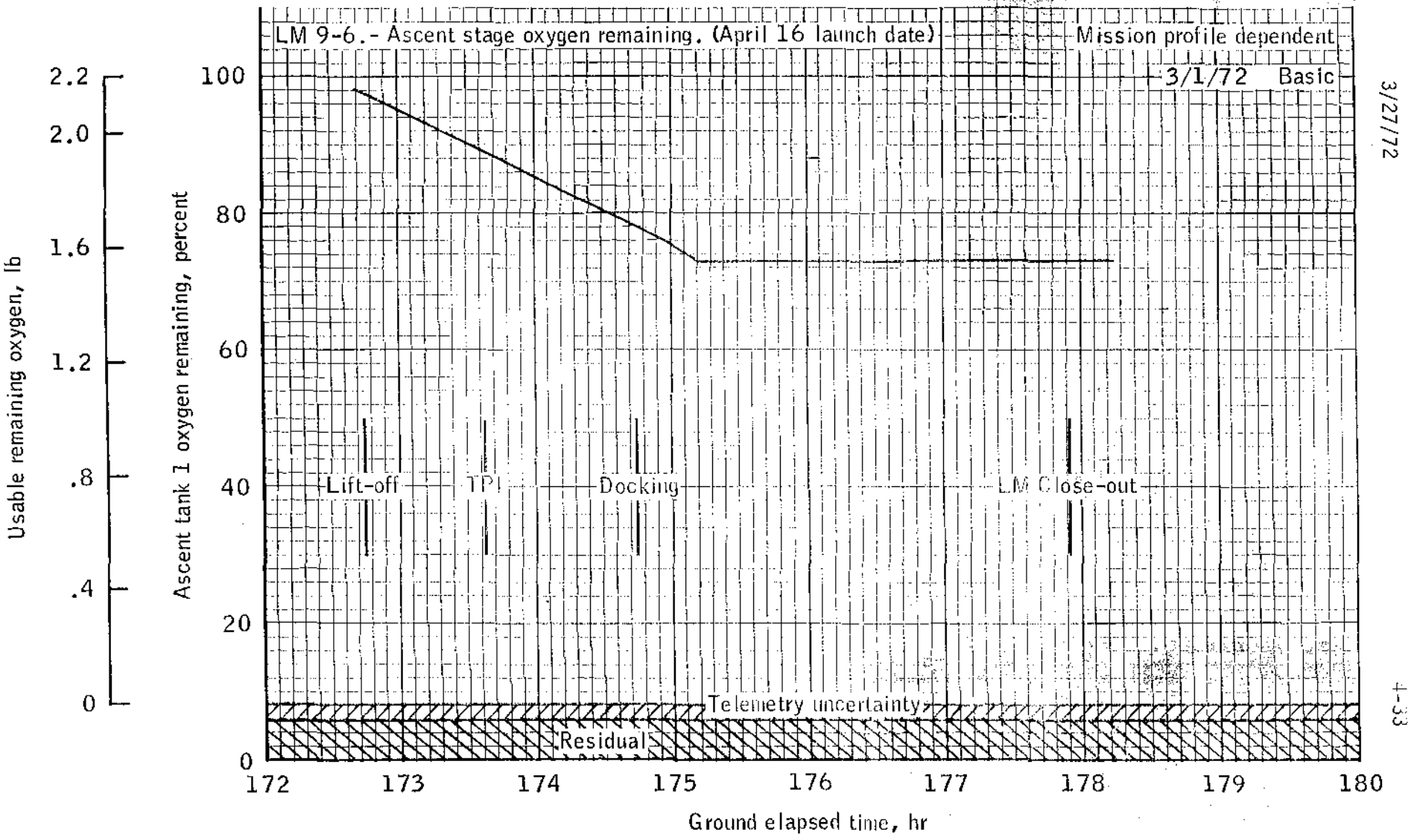
Descent stage water remaining.

Swaltn/SMB/MPAD (for LM Systems)
Data source Flight Plan & Supp
Data confirmed Bill Wade



Descent stage oxygen remaining.

3/27/72



Ascent tank 1 oxygen remaining.

Mission profile dependent
3/3/72 Basic

ASSUMPTIONS FOR THE LRV EPS ANALYSIS

a. The energy available from each of the two batteries is 121 A-h.

b. No unusables or uncertainties are considered in the budget. There is no way to establish a prediction uncertainty at this time.

c. Slopes were derived from the Apollo 16 landing site form line map.

d. Terrain types and stop times were derived from the traverse data package.

e. The MSFC soil model L-3 was used.

f. The vehicle speed was 8 km/hr except where mobility conditions dictated lower speeds.

g. The traction drive system was off during stops longer than 5 minutes.

h. The navigation and caution systems were operated throughout each traverse.

i. Electrical power required by the LCRU during EVA-1 and EVA-2 was supplied by LRV batteries. While driving, the LCRU was in the PM1/WB mode. During all station stops (EVA-1 and -2), except station 3, the LCRU mode of operation was FM/TV.

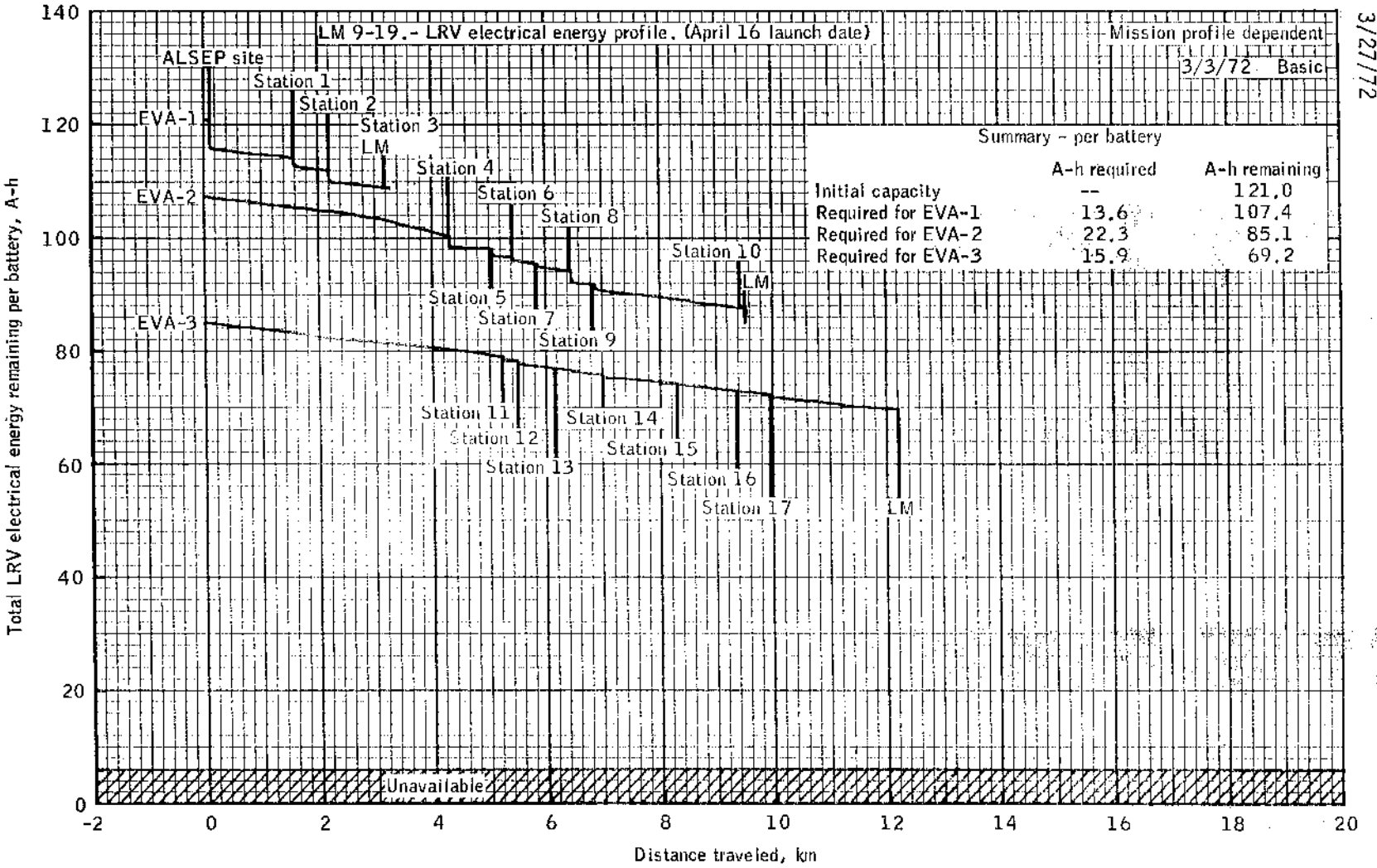
j. The vehicle weight was 1470 pounds.

k. A wander factor of 1.1 is included in the analysis.

l. The distance traveled is the map or straight line distance between points.

m. Clean battery radiators were assumed for all cool-down periods.

Ritchey/SMB/MPAD (for LM Systems)
Data source Traverse Plan 17 Feb 72
Data confirmed USR



LRV electrical energy profile.

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