BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D.C. 20024

B70 07101

SUBJECT: Saturn V Engine-Out Performance Capability - Case 310

DATE: July 31, 1970

FROM: K. P. Klaasen

ABSTRACT

A viewgraph presentation was made to Dr. R. A. Petrone on July 23, 1970 covering the topic of Saturn V performance capability with one or more engines out. In clarification of several issues raised during the presentation, "loss of control" of the launch vehicle has been defined, the dynamics of the vehicle for S-IC stage engine out prior to 10 seconds after lift-off have been described, and the go/no-go criterion for the TLI burn has been stated.

(NASA-CR-113018) SATURN 5 ENGINE-OUT PERFORMANCE CAPABILITY (Bellcomm, Inc.) 11 p

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MEMORANDUM FOR FILE

Attached are copies of the viewgraphs presented to Dr. R. A. Petrone on July 23, 1970 covering the topic of Saturn V performance capability with one or more engines out. The presentation included discussion of (1) the current Apollo program position regarding engine-out performance, (2) pre-mission Apollo 13 engine-out performance capability data, and (3) the payload effect of an engine-out malfunction.

The following points provide clarification of several issues raised during the presentation:

1. The regions labelled "loss of control" on the charts indicate those engine-out malfunctions that result in (1) a thrust-to-weight ratio that is too small to maintain a controlled trajectory or (2) subsequent gimbal angle commands that are too large for the engines to fulfill.

2. For the S-IC stage, any engine out prior to 0.2 second results in pad fallback. Any engine out between 0.2 and 0.9 second results in the vehicle colliding with the holddown posts. For a lower engine out (Figure 1) before 3.5 seconds, the resulting negative angle-of-attack combined with the normally prevailing tailwind leads to vehicle aerodynamic instability and loss of control in the high-q region. Tower collision occurs for one tower-side engine out prior to 5.6 seconds or for both tower-side engines out prior to 7.5 seconds; however, tower collisions are not included in the loss-of-control regions shown on the charts.* Apollo 13 Mission Rules require a launch abort in the case of any negative vertical motion of the vehicle. Negative motion will occur for any single engine out prior to about 1.9 seconds. A thrust-to-weight ratio of at least one will be maintained for one engine out occurring later than about 11 seconds.

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*Boeing Co. Document 5-9400-H-418, "AS-508 Saturn V Launch Vehicle Operational Flight Dynamics and Malfunction Flight Analysis," January 8, 1970.

3. The Mission Rules for Apollo 13 state that the TLI burn can be initiated if sufficient propellant remains to achieve a 65,000 n.mi. apogee elliptical orbit. No minimum probability of successfully completing the burn is listed.

K. P. Klaasen

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K. P. Klaasen

Attachments

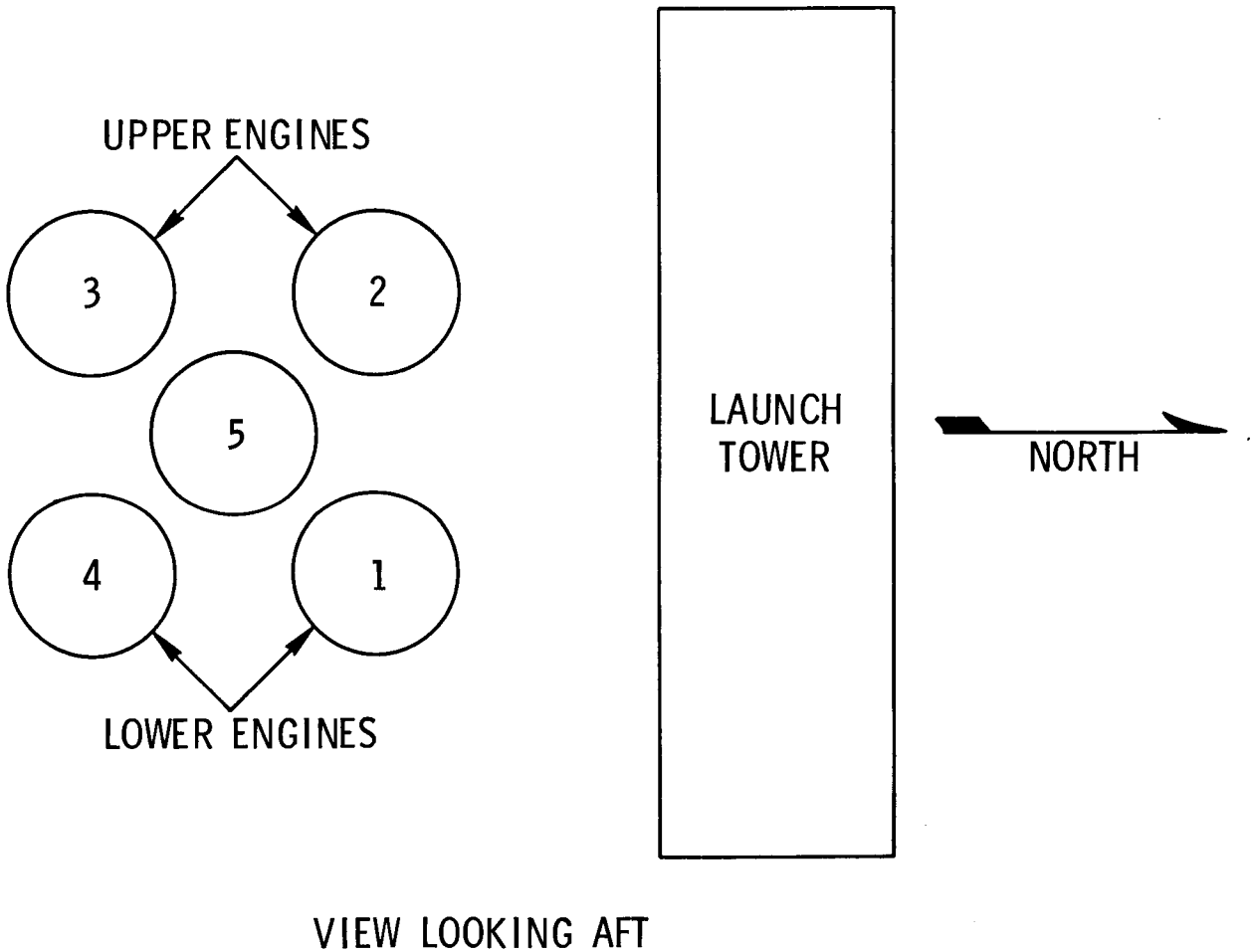


FIGURE 1 - SATURN V AND LAUNCH TOWER ORIENTATION

SATURN V ENGINE OUT MALFUNCTION

CURRENT APOLLO PROGRAM POSITION -

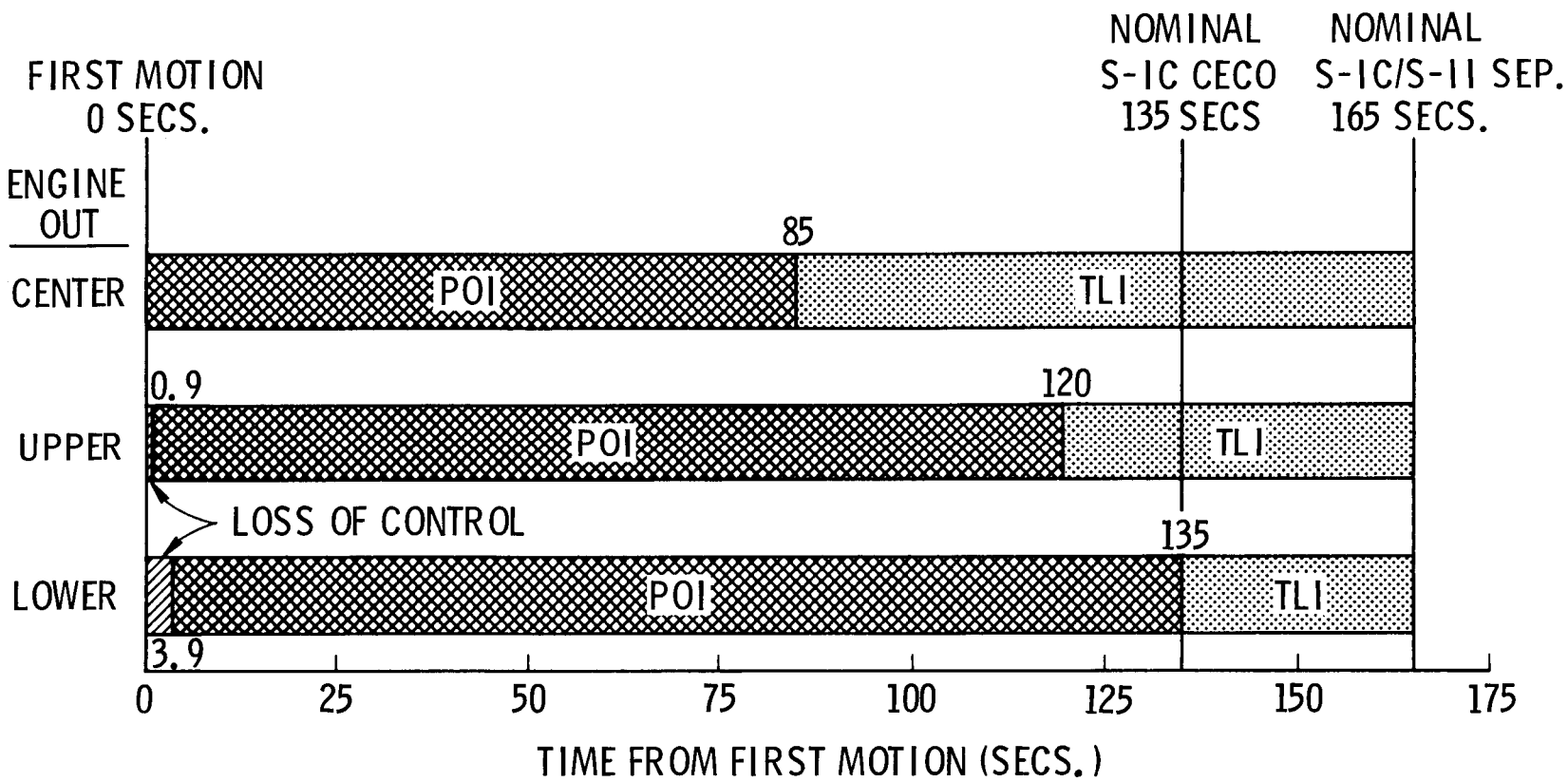
- PROGRAM SPECIFICATION REQUIRES LAUNCH VEHICLE STRUCTURE TO BEAR LOADS IMPOSED WITH ONE ENGINE OUT. LISTS NO PERFORMANCE OR CONTROL REQUIREMENTS.

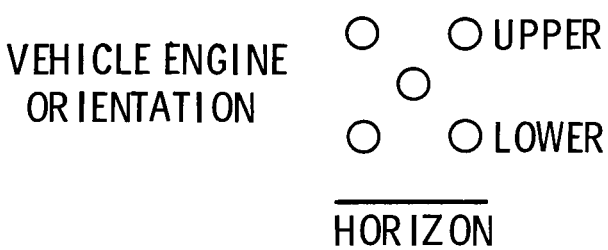
- FLIGHT MISSION ASSIGNMENTS REQUIRE
  - CAPABILITY TO REACH PARKING ORBIT WITH ONE S-IC ENGINE OUT AFTER 10 SECS. OF FIRST STAGE BURN.
  - CAPABILITY TO REACH PARKING ORBIT WITH ONE S-II ENGINE OUT ANY TIME DURING SECOND STAGE BURN.
  - CAPABILITY TO REACH PARKING ORBIT WITH S-II/S-IVB STAGING OCCURRING WITHIN 200 SECS. OF NOMINAL STAGING.

- MISSION RULES OUTLINE PROCEDURES TO FOLLOW IN EVENT OF ENGINE OUT. OPTIONS ARE
  - CONTINUE MISSION
  - ABORT
  - EARLY STAGE

- PERFORMANCE CAPABILITY WITH ENGINE OUT IS DETERMINED FOR EACH MISSION BY MSFC PRIOR TO MISSION.

S-IC SINGLE ENGINE OUT CAPABILITY
(APOLLO 13)





S-IC DUAL SIMULTANEOUS ENGINE OUT CAPABILITY
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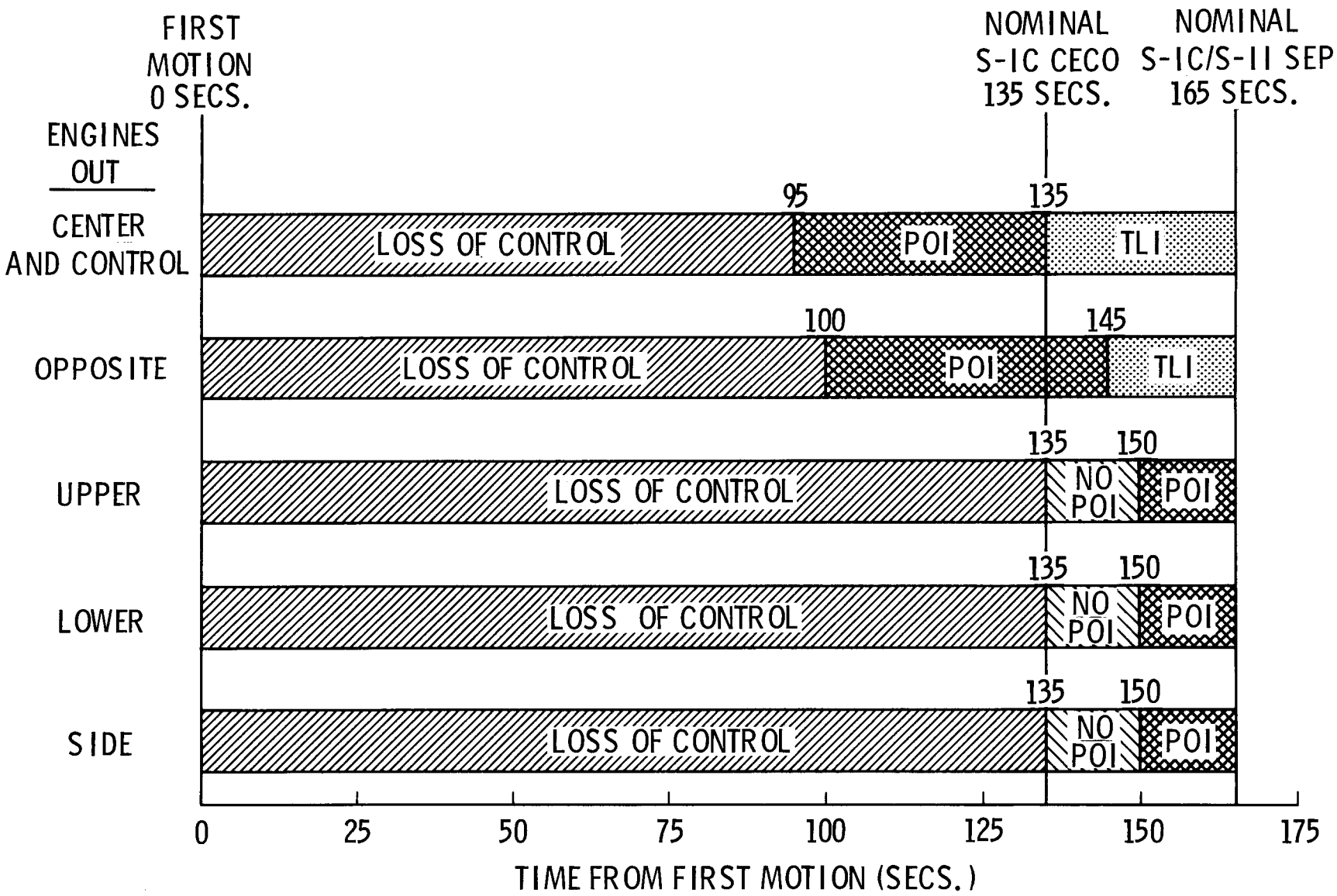
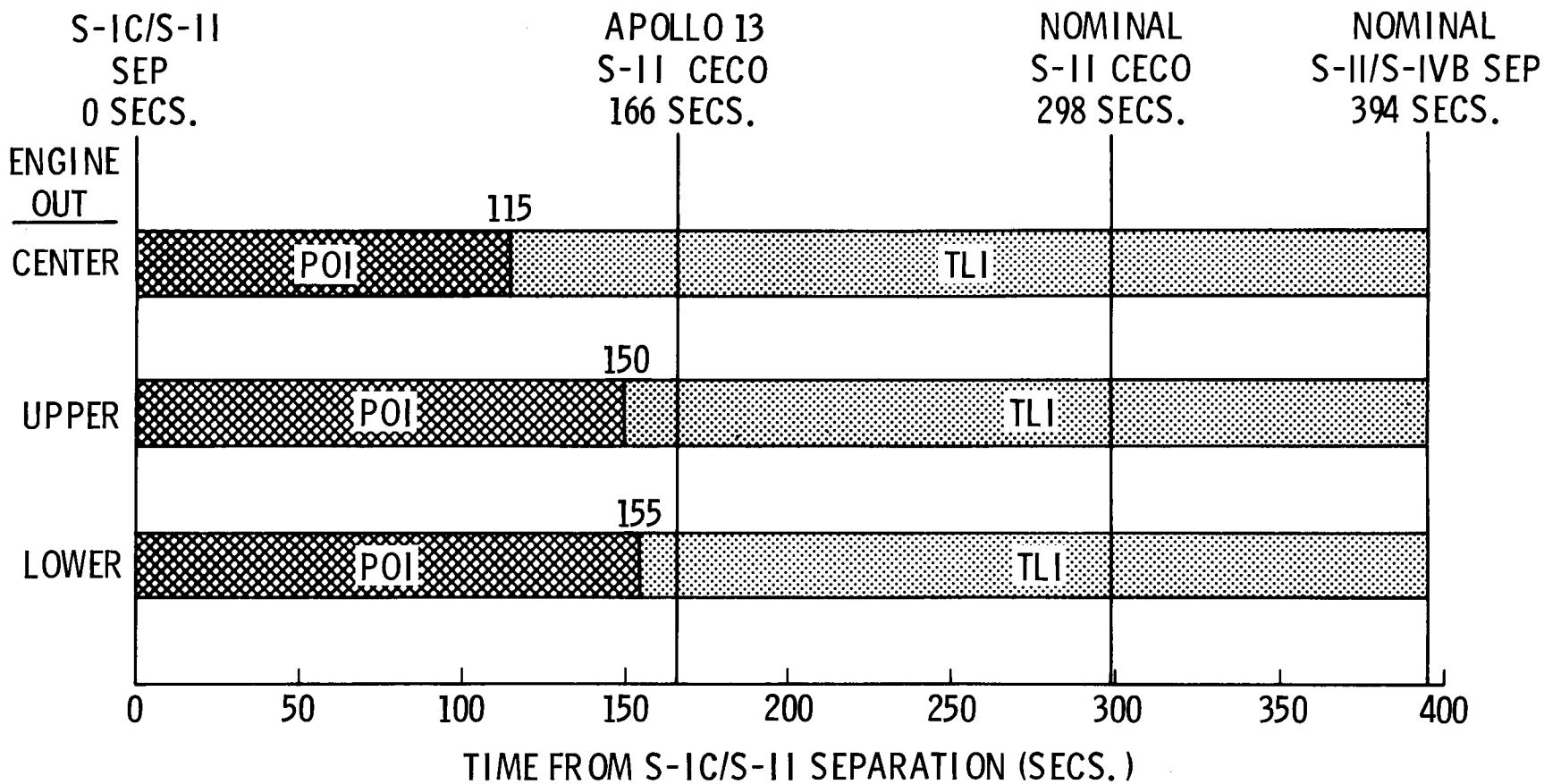
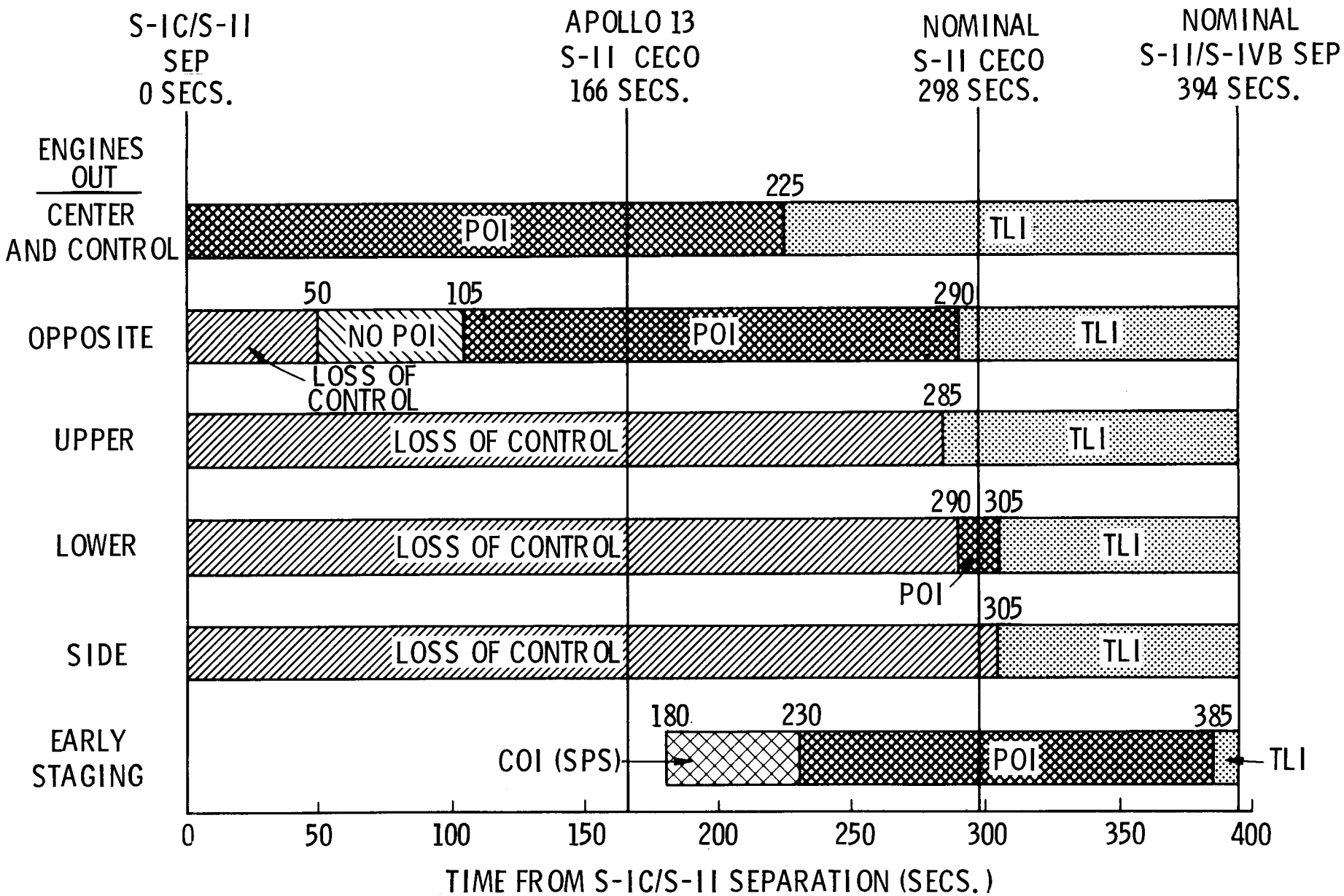


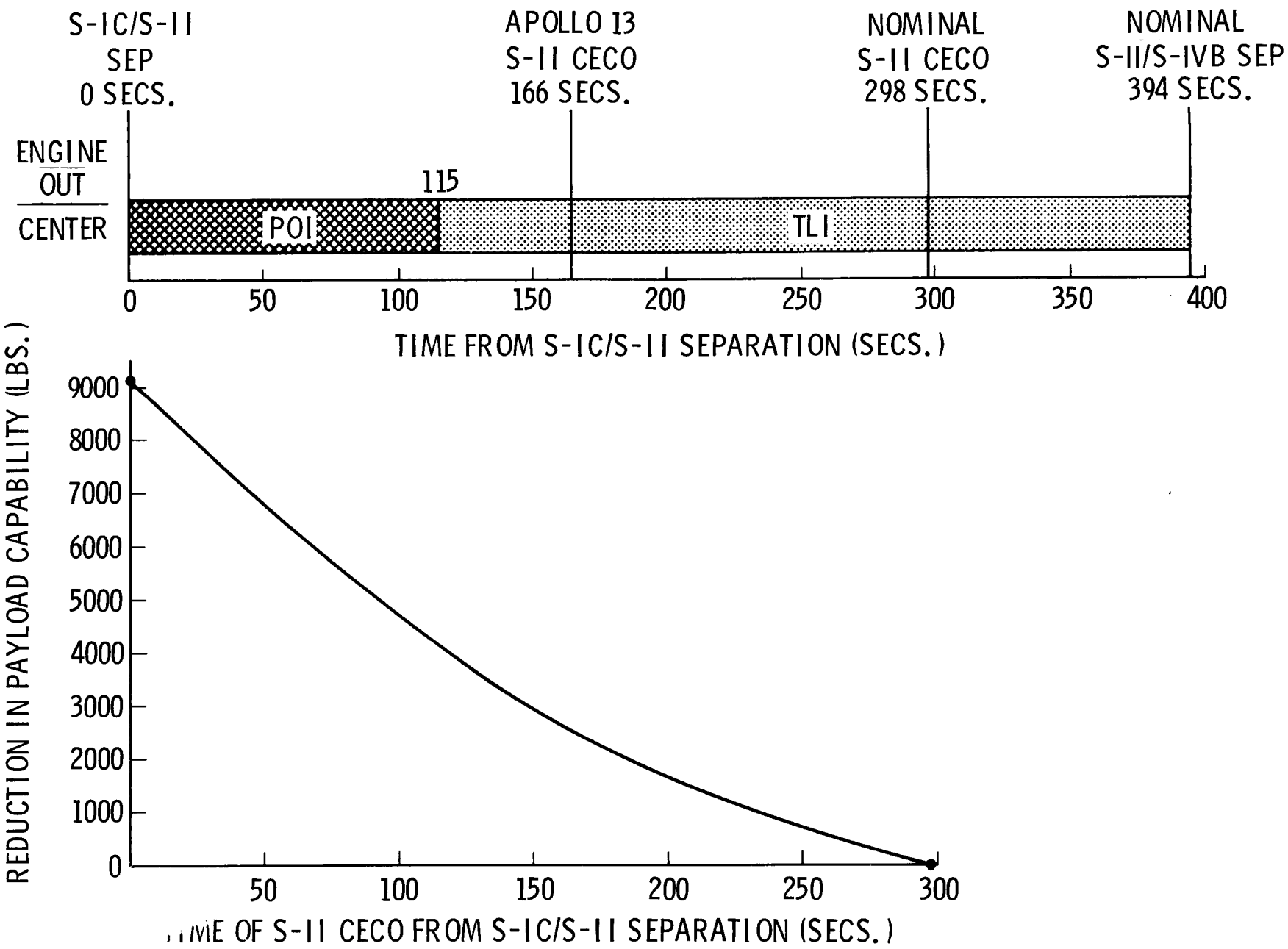
S-II SINGLE ENGINE OUT CAPABILITY
(APOLLO 13)



S-II DUAL SIMULTANEOUS ENGINE OUT AND EARLY STAGING CAPABILITY
(APOLLO 13)



PAYLOAD EFFECT OF S-II CENTER ENGINE OUT
(APOLLO 13)



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Subject: Saturn V Engine-Out Performance Capability

From: K. P. Klaasen

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