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Albert W. Holland, Ph.D.
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Albert W. Holland, Ph.D.
Lyndon B. Johnson Space Center
Houston, TX 77058

Stephen T. Vander Ark
KRUG Life Sciences
Houston, TX 77058

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**Behavior and Performance
Laboratory
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CONTENTS

TABLES

FIGURES

ACRONYMS

A/L	approach and land
A/S	airspeed
ADI	attitude direction indicator
ADTA	air data
AMI	alpha mach indicator
APIL	approach path indicator lights
APU	auxiliary power unit
AVVI	altitude/vertical velocity indicator
AZ	azimuth
BF	body flap
BRK	brake
BYP	bypass
CDR	commander
CMD	command
CNTRL	control
CRT	cathode-ray tube
CSS	control stick steering
D	drag
DAP	digital autopilot
DECEL	deceleration
DCLT	declutter
deg.	degree
E/I	entry interface
E/W	energy-to-weight ratio
EAS	equivalent airspeed
EDO	extended duration of Orbiter
EDW	Edwards Air Force Base
E/L	entry and landing
ENT TRAJ	entry trajectory
ET	external tank
EXEC	execute
FCOD	flight crew operations directorate
FLT CNTRL	flight control
fps	feet per second
FRCS	Forward Reaction Control System
g	gravity
G&C	Guidance and control
G-50	SPEC 50 display of HSD
GNC	guidance and navigational control
GPC	general purpose computer
GS	groundspeed
GR DN	gear down
H	altitude
HAC	heading alignment cone
HdblDot	altitude acceleration
Hdot	altitude rate *or* vertical velocity
HSD	horizontal situation display
HSI	horizontal situation indicator
HUD	heads-up display
HYD	hydrogen
IGS	inner glide slope
ISOL	isolation
KEAS	knots equivalent airspeed
KSC	Kennedy Space Center
KT	knot(s)
KYBD	keyboard
LG	landing gear
LOS	loss of sync
LRU	line replacement unit
LVLH	local vertical local horizontal
M	mach
MANF	manifold
MAX	maximum
MBCS	motion-based crew simulator
MCC	Mission Control Center
MLS	microwave landing system
MM	major mode
MOD	Mission Operations Directorate
MPS	main propulsion system
MS2	mission specialist 2
NAV	navigation
NWS	Nose Wheel Steering
N_y	normal acceleration
N_z	lateral acceleration
OGS	outer glide slope
OPS	operational sequence
P	pitch
PAPI	precision approach path indicator

PB	push button
PBI	push button indicator
PLT	pilot
POS	position
PRO	proceed
psf	pounds per square foot
PWR	power
qbar	dynamic pressure
R/Y	roll/yaw
RAD	radiator bypass valve
RCS	reaction control system
RHC	rotational hand controller
SEP	separation
SME	subject matter expert
SPDBK	speedbrake
SPEC 50	horizontal situation display
SPI	surface position indicator
SRB	solid rocket booster
SUMM	summary
SYS	system
TACAN	Tactical Air Command and Navigation
TAEM	Terminal Area Energy Management
TIG	time of ignition
TVC	thrust vector control
UHF	ultrahigh frequency
vel	velocity
VERT SIT	vertical situation
VLV	valve
V_{rel}	relative velocity
VSD	vertical situation display
WONG	weight-on-nose gear
WOW	weight on wheels
WOWLON	weight on wheels locked on
WP 1	way point one

TASK ANALYSIS OF SHUTTLE ENTRY AND LANDING ACTIVITIES

ABSTRACT

The Task Analysis of Shuttle Entry and Landing (E/L) Activities documents all tasks required to land the Orbiter successfully following an STS mission. In addition to the analysis of tasks performed, conditions surrounding each task or series of tasks is included. These conditions encompassed, for each task, the estimated time required for completion, altitude, relative velocity, normal acceleration, lateral acceleration, location of controls being operated or monitored, and level of g's experienced.

The present analysis precedes further investigations into the potential effects of zero g on the piloting capabilities of crewmembers responsible for landing the Orbiter following long duration missions. This includes, but is not limited to, researching the effects on piloting capabilities following extended duration Orbiter missions.

Four primary constraints of the analysis must be explicated: (1) the analysis depicts E/L in a static manner; whereas, the actual process is dynamic; (2) since it was not feasible to conduct research to conduct research in the actual setting (i.e., observing and filming during an actual E/L), the task analysis was limited to information obtained from E/L documentation and observation of E/L simulations; (3) the tasks included are those required for E/L during nominal, daylight conditions; and (4) certain E/L tasks will vary according to the flying style of each commander.

BACKGROUND

A task analysis is typically conducted to define a job by breaking it down into its respective components, including the conditions under which the tasks are performed. This facilitates identifying specific units of a job for further scrutiny. The purpose of the present analysis was to identify the requisite tasks performed by the commander (CDR), pilot (PLT), and mission specialist 2 (MS2) to land the Orbiter successfully . The information contained in this document is intended for use by organizations requiring entry and landing (E/L) task information for operational planning or research purposes.

Included in the present analysis was a hierarchical assessment of all crewmember activities that occur during E/L, including Orbiter events and the environment surrounding the crew as they accomplish the tasks. Conditions under which crewmembers must perform include the following variables: (1) elapsed time, (2) altitude (H), (3) relative velocity (V_{rel}), (4) normal acceleration (N_y), (5) lateral acceleration (N_z), (6) location of controls, and (7) level of g's experienced. Gravitational force was not included in the task analysis template but was graphed separately (appendix A) to display the g's experienced during a typical E/L. Combined, the above information explains the process of E/L in detail and provides the basis for various analyses examining current or extended duration Orbiter (EDO) mission E/Ls. This procedure was analogous to that used by Keller, Lesser, Norman, and Webster (1965) in their detailed analysis of tasks to be performed by crewmembers during lunar excursion module activities.

To date, the missions flown have ranged in length from 2 to 13 days. Some CDRs, PLTs, and MS2s of these missions expressed that they have, at various points of E/L, experienced a somewhat less than optimal capability for performing their tasks. This may be due, in part, to the adaptation from zero-g to 1g, which they begin while in the dynamic environment of reentry. During this time, the CDR, PLT, and MS2 must monitor controls for nominal and contingency events, engage and disengage control systems, and conduct manual flight and landing procedures. This is accomplished under a high relative velocity (V_{rel}) and varying levels of normal and lateral acceleration.

An important consideration to be addressed prior to the onset of EDO missions is the E/L performance of the three crewmembers. A few individuals have reported that during E/L on previous missions, certain limitations have been experienced. It is not known whether extended time in zero g will accentuate difficulties previously reported or will possibly create additional difficulties in piloting performance. An analysis of this type provides the basis for assessing whether the CDR, PLT, and MS2 could be further affected by exposure to zero g for periods longer than 13 days. Also, at what point in the E/L procedure would these difficulties most likely occur? A task analysis was first conducted, therefore, to define precisely what is performed during E/L. Such an analysis facilitates any assessment of questions regarding the tasks and surrounding conditions.

Note that this task analysis was current as of November 1991. Any tasks appearing in this analysis will not reflect changes made to E/L procedures after that date (e.g., addition of the drag chute to landing procedures).

SCOPE OF THE ANALYSIS

Constraints

To complete this analysis, several groups of E/L subject matter experts were consulted. In addition, data obtained from all available documentation pertinent to E/L were incorporated into the analysis. However, the nature of this procedure and the methods available for analysis introduce certain constraints as to how this analysis should be viewed. Limitations to consider in using the information presented in this analysis include the following:

- The analysis depicts E/L in a static manner; whereas, the actual process is dynamic.
- This task analysis is based upon a nominal landing during daylight hours. Any number of anomalies may occur, and piloting styles may differ; this would alter the tasks presented in the task template. Examples of such deviations would include malfunctions in mechanical systems and/or wind conditions differing from that which was anticipated. These or any off-nominal E/L scenarios would require a more complex set of tasks, more frequent head movements, and an increased use of checklists and cue cards. Therefore, presenting all probable scenarios or incorporating subtle differences relative to a pilot's flying are not feasible within the scope of this analysis.
- This project was limited to the information that could be obtained from E/L documentation and observation of E/L simulations, since it was not possible to access the actual setting. No filming or observing was conducted during an actual E/L sequence; simulations in the motion-based simulator and verbal reports from PLTs, CDRs, and MS2s were used to verify the accuracy of the task sequences.
- The analysis does not consider each mission CDR's flying style or preferences regarding how and when E/L procedures are performed.

The focus of this analysis was on the tasks performed by the three crewmembers from 5 minutes prior to entry interface (E/I) through wheel stop. Preparations for E/L completed prior to this time were omitted from the analysis. All tasks are presented hierarchically in column format, detailing activities required to accomplish specific tasks. Additional detail was provided regarding crewmembers' actions during events controlled by the general purpose computer (GPC) in the control stick steering (CSS) phase of the analysis. This was included since the requisite tasks performed by crewmembers increase significantly, and manual piloting of the Orbiter begins.

When E/I occurs, elapsed time is recorded in ascending order, beginning at 00:00. Approximately 30 minutes is required to reach the point of wheel stop; however, as previously noted, between-mission differences exist among times to complete E/L. A primary factor influencing the timeline for completion of tasks is flight path. This can deviate because of many variations, including energy parameters, wind conditions, Orbiter weight, orbital inclination, landing site chosen, and the heading alignment cone (HAC) selected at the landing site (figs. 1, 2, and 3). All tasks accomplished during E/L are encompassed within three distinct segments, each requiring varying lengths of time to complete (table I). Each segment is separated into specific phases, during which a prescribed set of tasks must be performed. The tasks follow in a hierarchical fashion to delineate what is necessary for completing that portion of the segment successfully.

Following are the rudimentary assumptions used while completing the task analysis:

- E/I occurring at 400,000 ft.
- Lightweight Orbiter (< 220,000 lb.)
- Nominal energy parameters
- No equipment malfunctions
- No alarms sounding onboard the Orbiter, which signal off-nominal events
- Landing during daylight hours
- Nominal wind and weather conditions
- Nominal operation of ground-based guidance systems
- Approximately 30 minutes required from E/I to wheel stop
- Nominal runway conditions at Edwards Air Force Base, California (Edwards runway 22)

Method

Data were collected at NASA JSC from the Flight Crew Operations Directorate (FCOD) and Mission Operations Directorate (MOD). Several sources were consulted to obtain the information to complete the analysis, including the following:

- Subject Matter Experts (FCOD and MOD personnel),
- Guidance and Navigational Control (GNC) data from previous E/Ls (STS -26, -41, and -39),
- Observation of E/Ls in the Motion-Based Crew Simulator (MBCS)
- Flight Procedures Handbook (JSC-16873, July 1989),
- Shuttle Systems Handbook (JSC-11174, July 1989),
- Training and Procedure Manuals (SSV FAM 1107, August 1986; CSI 2102, November 1987; ENT GUID 2102, July 1988),
- Computer-modeled simulation of head movements.

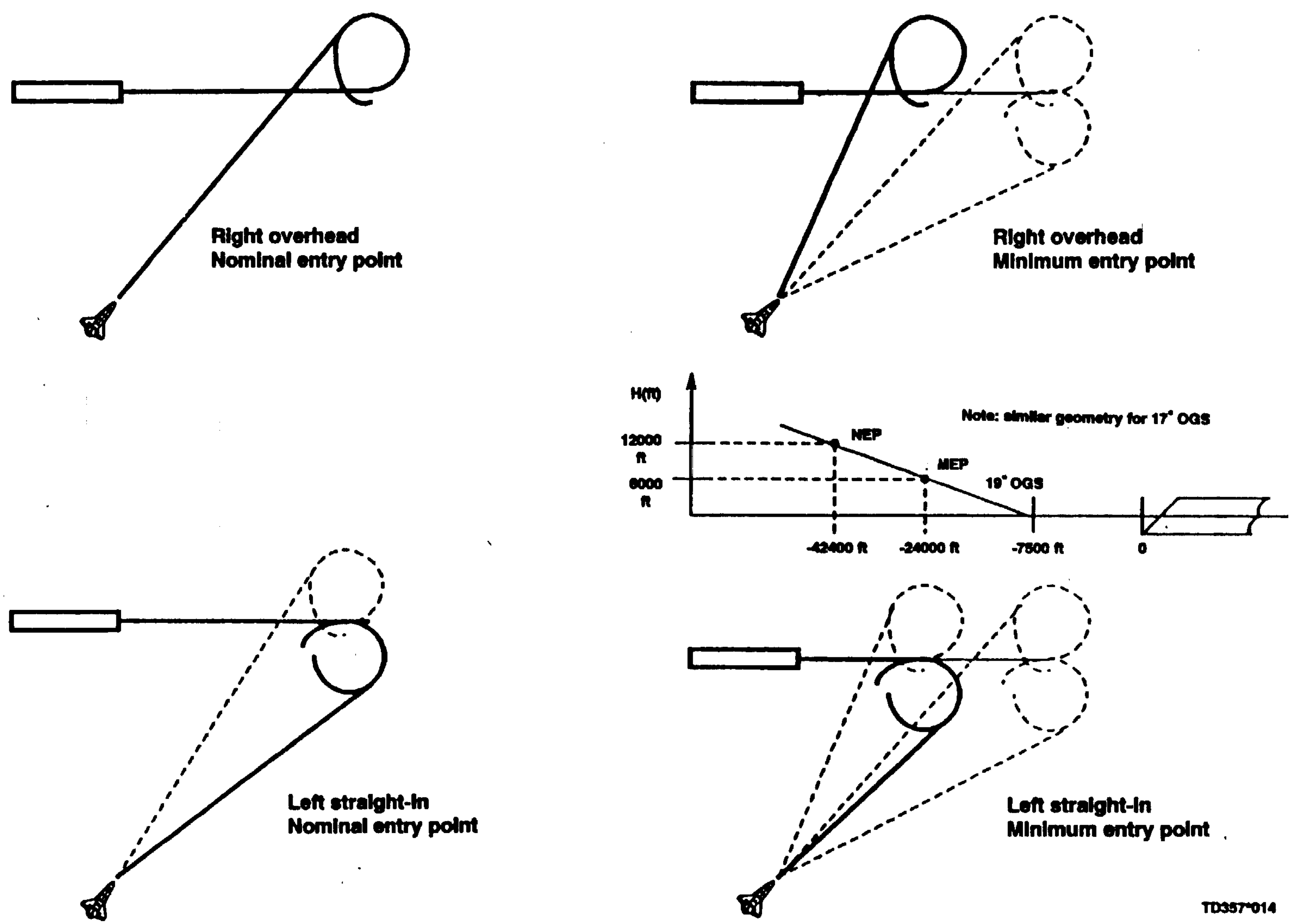

Figure 1. - Optional TAEM targeting HACs.

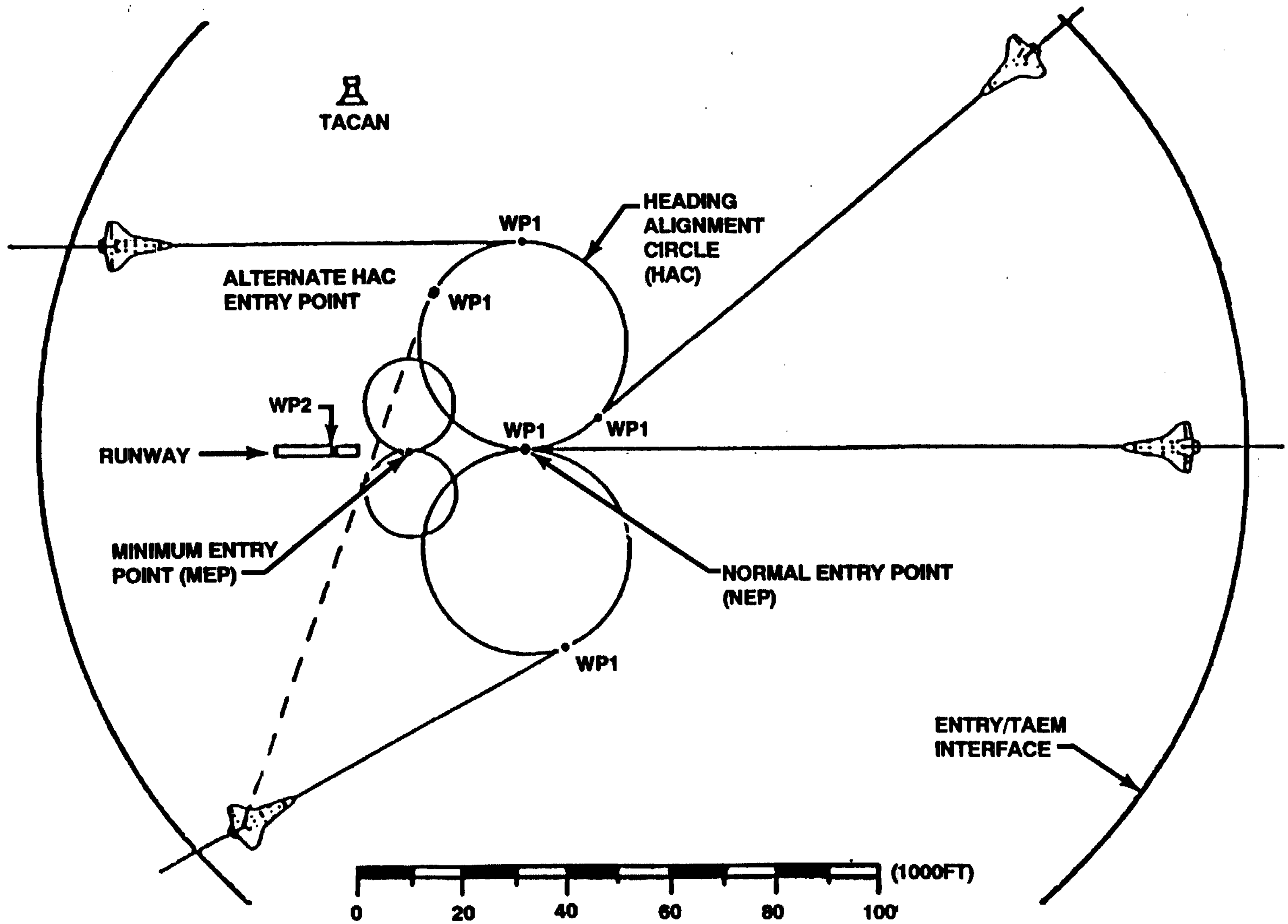

Figure 2. - Flight path geometry - top view.

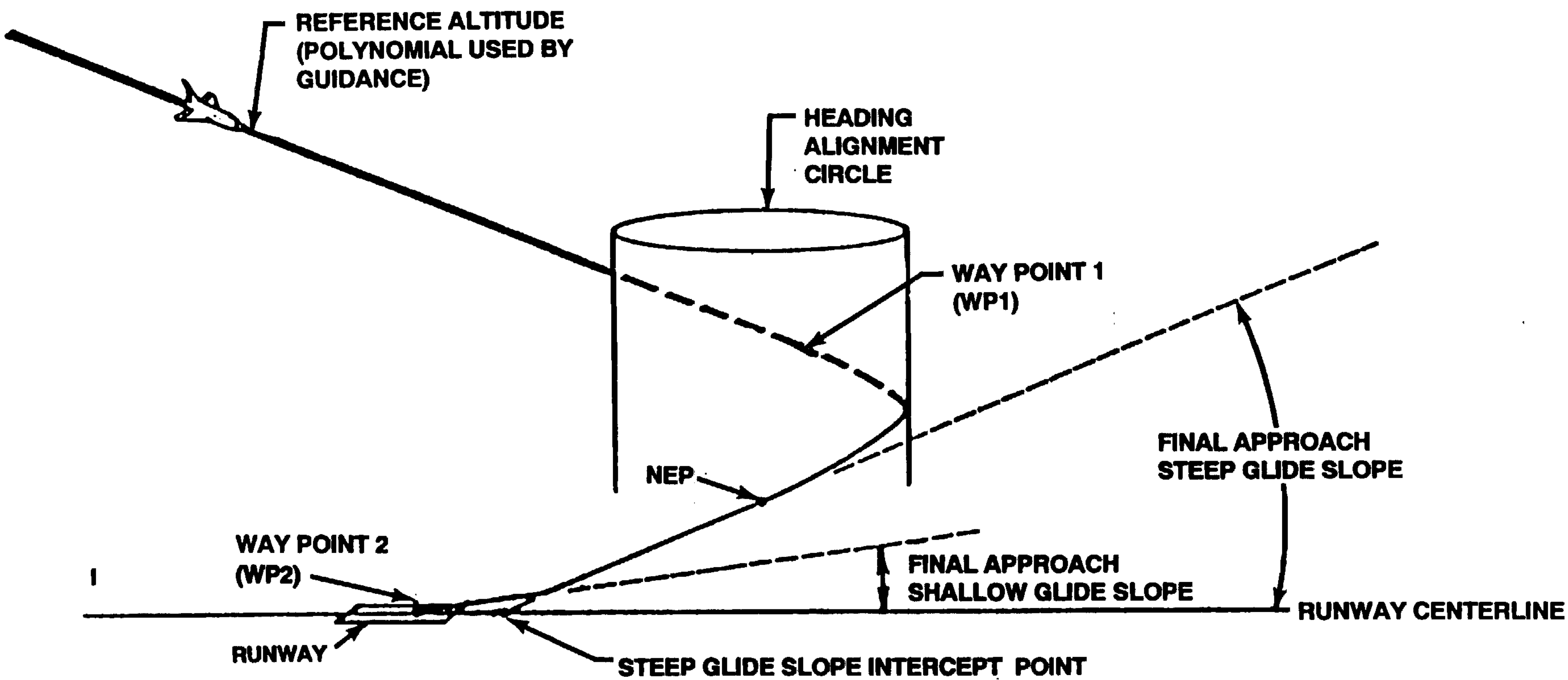

Figure 3. - Flight path geometry - side view.

Since information had to be assimilated from several persons and reference materials, the decision was made to conduct the analysis iteratively, proceeding from a general to a specific format. The first phase involved producing a general outline of E/L using flight procedure handbooks, training manuals, and observation of E/Ls in the MBCS. The initial outline encompassed the major Orbiter events (table I), which are controlled by the onboard GPC throughout E/L; the timeframe at which they occur; and the corresponding altitude. Information listed in table 1 is also represented graphically in figures 4, 5, and 6. The initial outline also contained subsequent tasks required during the major Orbiter events. From this outline, extensive detail making up the final product was incorporated, with revisions and comments coming primarily from SMEs and GNC data. SMEs included E/L instructors and GNC experts from MOD, as well as crewmembers currently serving as CDRs, PLTs, and MS2s. Reviewers checked the accuracy of tasks listed, provided additional requisite tasks, organized them into their proper sequences, and assigned tasks to the appropriate crewmembers. Iterations such as these continued until a consensus was reached between FCOD, MOD, and the researchers that an effective portrayal of the tasks required to perform a nominal E/L successfully had been attained.

Table I. - Segments, Phases, and Subphases of Entry and Landing

Entry Segment (≈24:09)

- Preentry Phase (≈4:36)
- Temperature Control Phase (≈8:26)
- Equilibrium Glide Phase (≈2:48)
- Constant Drag Phase (≈1:40)
- Transition Phase (≈6:39)

TAEM Segment (≈5:00)

- Acquisition Phase (≈2:51)
  - Arc Subphase (N/A)
  - Line Subphase (N/A)
- Heading Alignment Phase (≈1:50)
- Prefinal Phase (≈0:19)

Approach and Land Segment (≈1:50)

- Trajectory Capture Phase (N/A)
- Outer/Steep Glide Slope Phase (≈0:43)
- Preflare Phase (≈0:14)
- Inner/Shallow Glide Phase (≈0:10)
- Final Flare (≈0:12)
- Touchdown and Rollout Phase (≈0:31)

( ) contain the approximate time required to complete that particular segment, phase, or subphase.
N/A is listed where an accurate estimate of time could not be obtained.

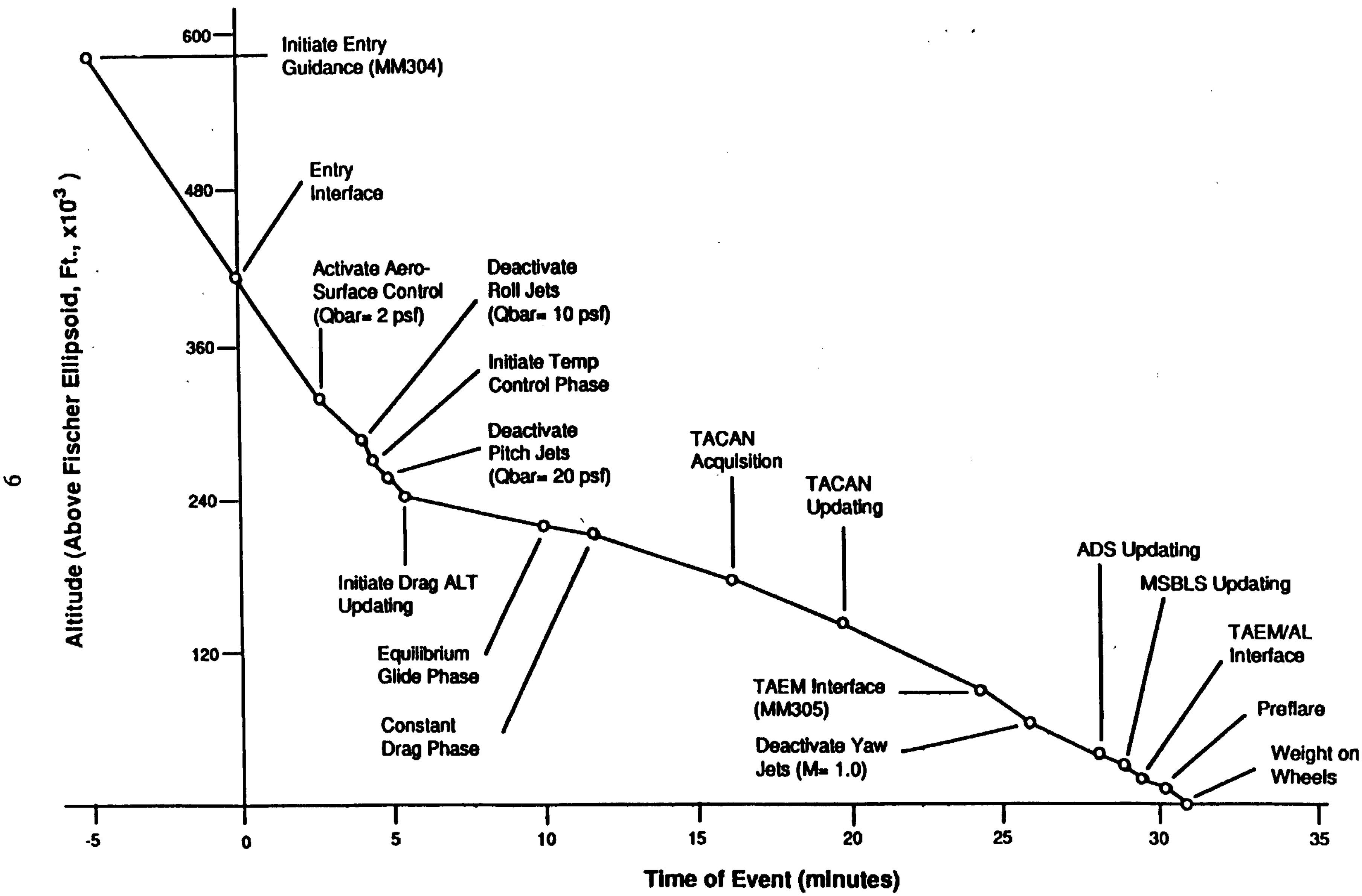

Figure 4. - GNC major events.

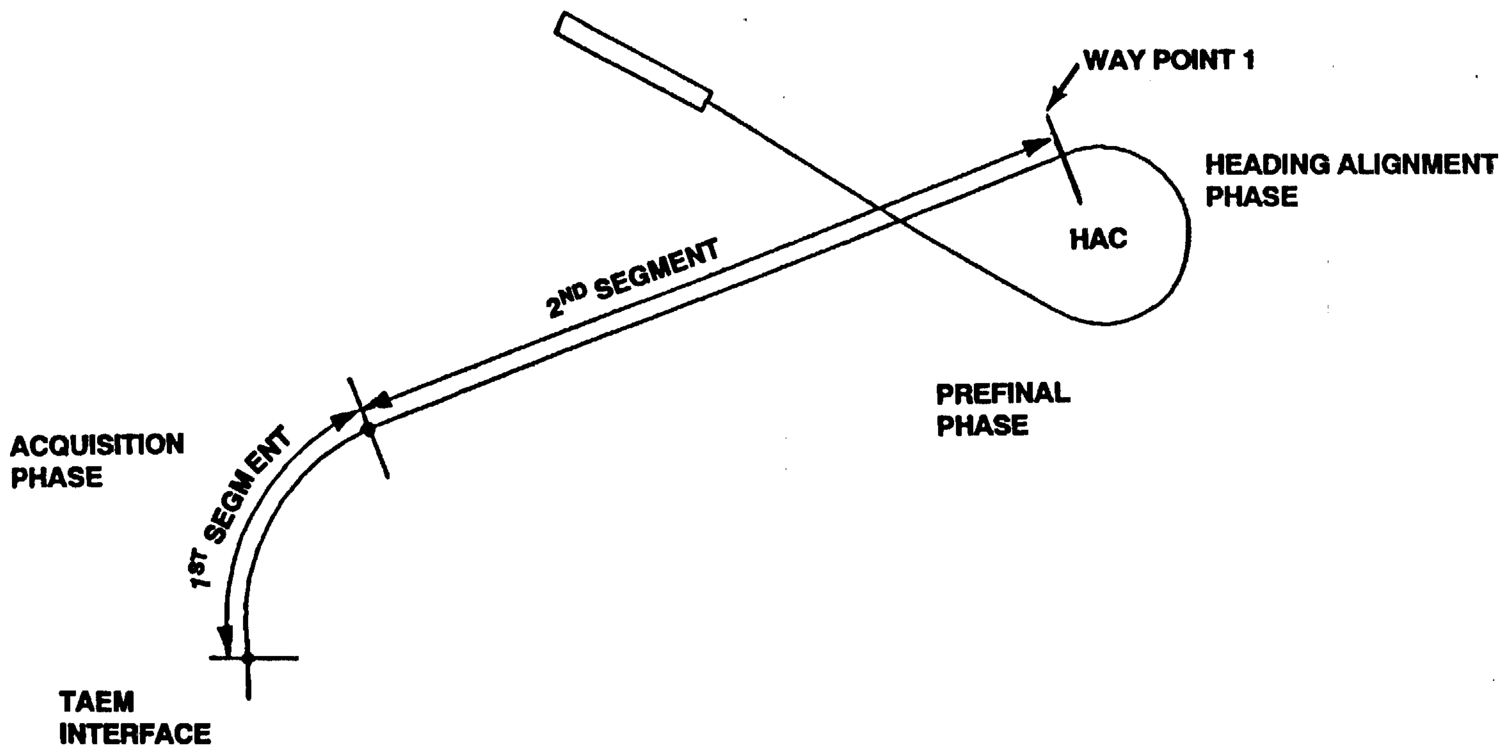

Figure 5. - TAEM segment.

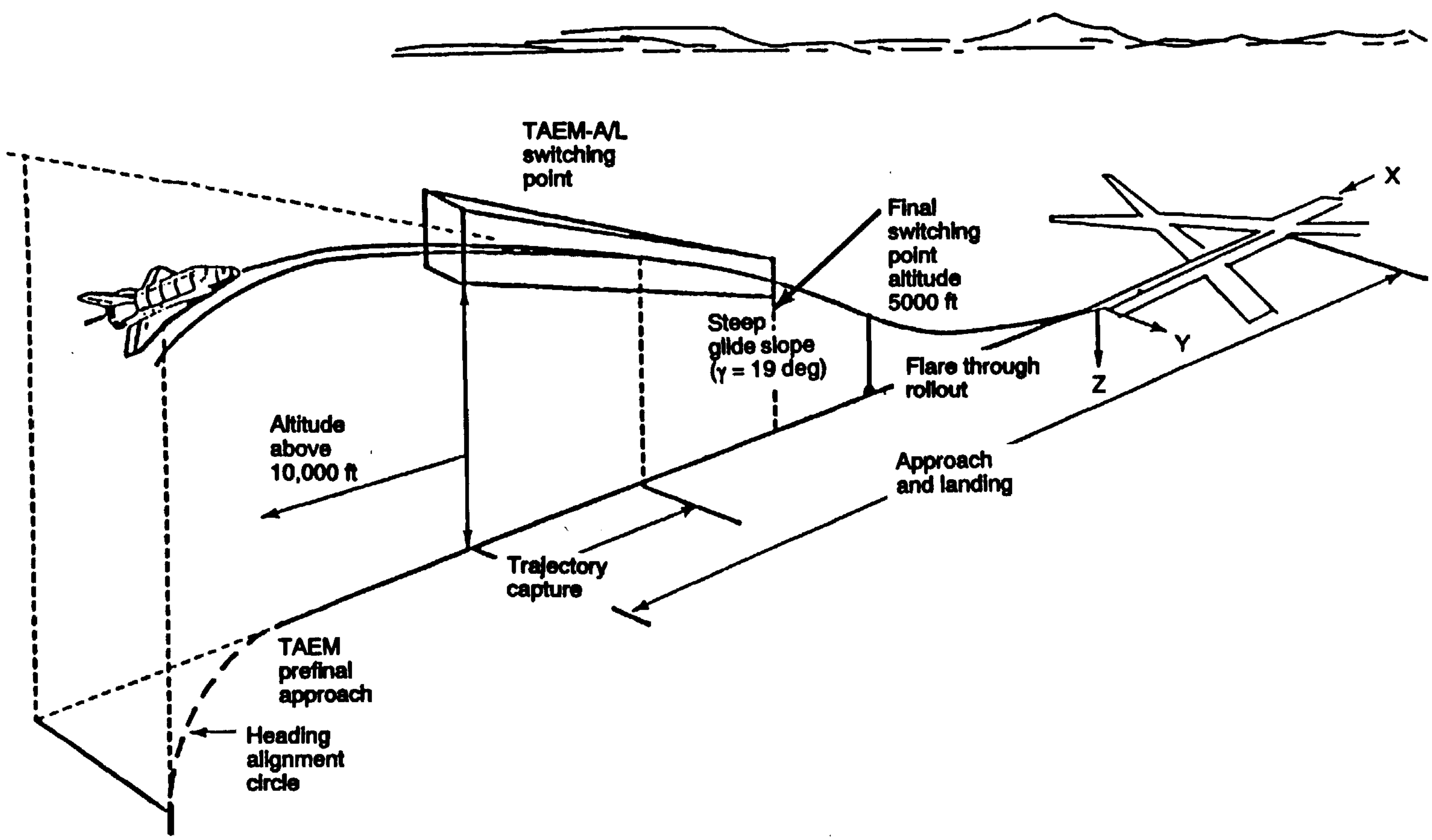

Figure 6. - A/L segment.

ANALYSIS TEMPLATE DEFINITION

Column Headings and Contents

The information obtained during the iterative process previously described is compiled into a hierarchy using a column format template. The rationale for applying this format is the sequential nature of the E/L procedures and that a majority of the tasks being completed are well defined and chronologically ordered. The column format also provided a means for presenting the numerous set of tasks assigned to crewmembers that are performed simultaneously.

The column variables in the analysis contain the minimum required to accurately describe the E/L procedure as a whole. The first five columns reference the conditions and constraints under which tasks are performed, including elapsed time, altitude, Orbiter velocity, lateral acceleration, and normal acceleration. The subsequent four columns comprise the tasks performed by crewmembers and the location and control in the forward flight deck (fig. 7), which is monitored or manipulated during E/L.

The following is an explanation of what each column in the template contains:

El Time: Elapsed time from entry interface. Time is listed in ascending order, beginning at 00:00.

Alt Kft: Altitude in thousands of feet.

V_{rel} Kfps (M): Relative velocity of the Orbiter, which is provided in thousands ft/s (can also be read as "mach"). During the touchdown and rollout phase (El Time 30:28), the velocity measurement is displayed in knots (KT), since crewmembers use this reading as a cue for certain tasks to be initiated.

N_y: Lateral movement: Lateral acceleration in ft/s^2.

N_z: Vertical movement: Normal acceleration in ft/s^2.

Events/CDR Task: Orbiter events occurring automatically, as well as tasks performed by the commander.

Note that Orbiter Events occurring automatically, major segments, and the phases corresponding to each segment are listed in the CDR column only, but apply to all crewmembers. Tasks performed by the CDR, PLT, and MS2 appear in their respective columns. If the same task is performed by more than one crewmember, it is identified in all applicable columns.

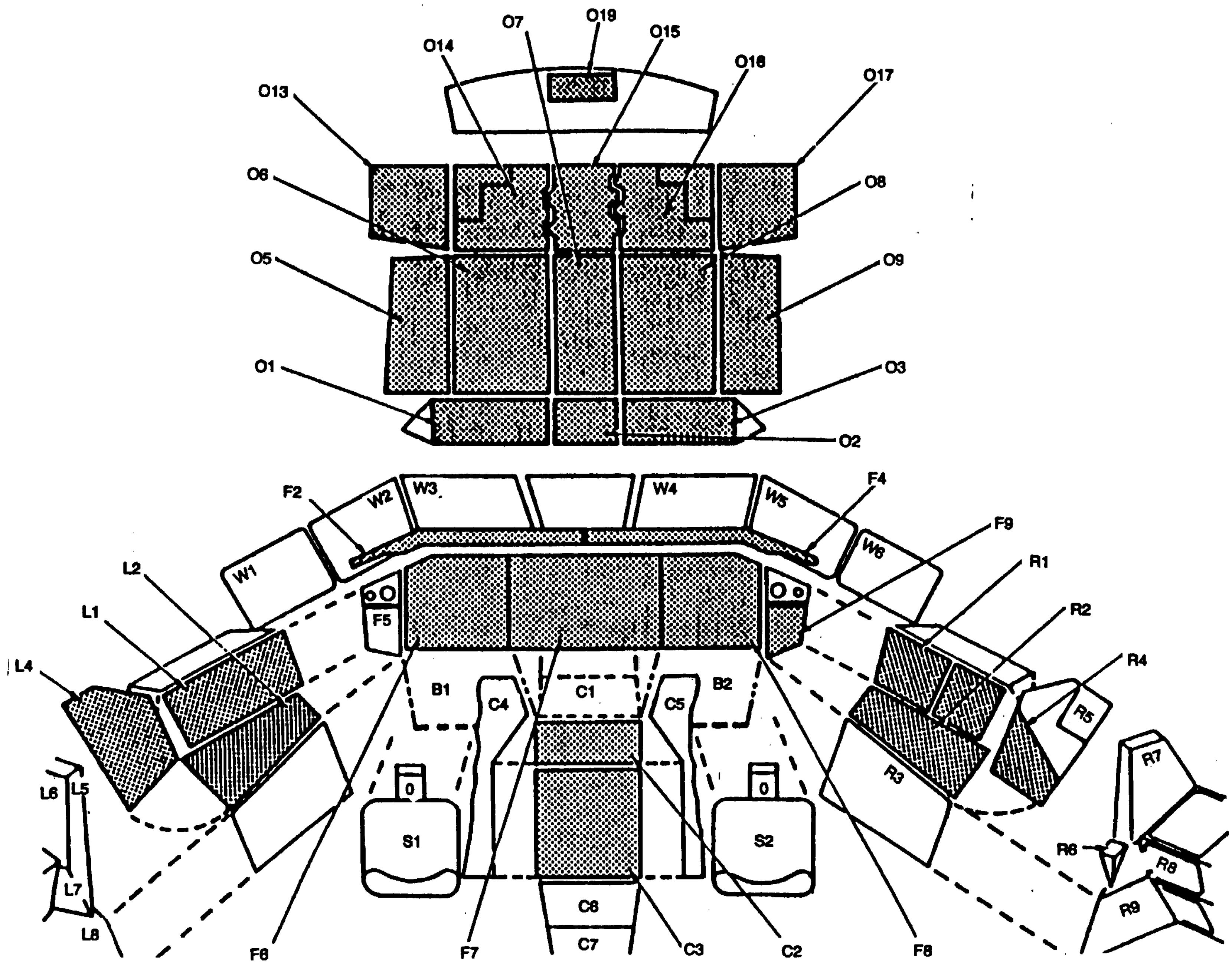

Figure 7. - Forward flight deck panels.

Pilot Task: Tasks performed by the PLT.

MS2 Task: Tasks performed by the Mission Specialist 2.

Loc: Location of controls or instruments involved in the task or sequence of tasks.

Notes: Comments to the reader on specific events or tasks.

Coding System

The level of detail contained within the task template necessitated the development of a nomenclature for organizing and labeling the segments and phases, with their respective tasks and subtasks, for each crewmember. This system was used to iterate the sequence of the tasks and to facilitate references to specific portions of the document. An example of the coding system used for this analysis appears in table II. Each entry in table II is identified by a circled number corresponding to the subsequent explanation of what the item represents.

Table II. - Example of Task Coding System

01 Begin Entry Segment (~24:09). (1)
 01.01 MM304 Initiation. (5)
  001 Type "OPS 304 PRO." (6)
  002 Check LVLH Attitude (0,40,0) on CRT (6)
  003 Check FRCS MANF 1-4 closed. (6)
Entry Interface. (4)
A01 Begin Preentry Phase (~4:36). (2)
 A01.01 Monitor alpha, qbar, phi, and drag-vel-range profile on ENT TRAJ 1 and Entry-Alpha Cue Card. (5)
Auto elevon trim @ qbar=0.5. (4)
 A01.02 Monitor Entry DAP. (5)
  001 Monitor elevons. (6)
  002 Monitor body flap. (6)
  003 Monitor RCS jet activity lights for off-i configuration/usage. (6)

1) ALL CAPS + **BOLD** + Underlined = Entry and Landing *Segments*. These are identified by a two-digit number (01, 02, or 03), which precede the segment title. Parentheses following these entries contain an approximate time required to complete each segment.

2) ALL CAPS + **BOLD** + *Italicized* = *Phases* of E/L Segments. Upper case letters connote the sequence of each phase within a segment. These letters precede the two-digit numbers identifying the corresponding segments. Parentheses following these entries contain an approximate time required to complete the phase. Aggregate time for completing phases equals the time required to complete their associated segment.

3) ALL CAPS + *Italicized* = Subphases/Components of Phases. Phases that can be broken down into discrete units are only identified via this formatting; they are not specified with sequential numbering.

4) *Italicized* = Events occurring automatically, controlled by the Orbiter onboard computer.

Note that events controlled by the Orbiter GPC are not explained in detail until CSS begins (approximately 26:27 elapsed time), the reason being that when CSS begins, the crew is flying the Orbiter manually in addition to their monitoring and verifying activities. During that period of time, it is important to know the precise division of labor required to verify computer accuracy and timely operation.

The descriptions appear in the column of the crewmember whose function it is to verify or monitor the occurrence of the GPC-controlled event. These events are not sequentially numbered.

5) Regular Type = Task Statements. Each is identified with a letter followed by 4 digits (e.g., A01.01). The task number is identified following the decimal point in the sequence. Tasks are numbered in sequential order to show what must be completed during a particular phase. The statements begin with an underlined verb to emphasize the action that is required.

6) Indented + Regular Type = Subtasks. They describe what is necessary to complete the associated task successfully. Each is identified with a 3-digit number (001, 002, etc.). Subtasks are omitted in instances where the task does not require further explanation. As with tasks, subtasks begin with an underlined verb to highlight the type of activity being performed.

Note that the tasks required during transitions into new segments cannot always be inserted under a specific phase. These tasks, therefore, are identified without a letter that would link it to a phase. In the present example, the task "01.01" and its subtasks appear at the introduction to the segment and prior to the first phase. This also occurs in the transitions to segments 2 and 3.

To obtain the location of controls operated and monitored during E/L, the *Space Shuttle Systems Handbook*, Volume II, Section 20 (July 1989) was consulted. This portion of the task analysis document identifies, by name, each control used to perform the corresponding task(s) and its location according to the flight deck panel coordinate system. The forward flight deck coordinate system comprises the following, which are also presented in figure 7.

F= forward panels, directly in front of the CDR and PLT

R= starboard side panels, to the PLTs right

L= port side panels, to the CDRs left

C= console panels, between CDR and PLT

O= overhead panels, above CDR, PLT, and MS2

Each area contains several panels, which are identified as F1 to F8 for the forward panels: C1 to C7 for the console, and so forth. Most panels are divided into sections to further define control locations. These are identified with the letter "A." For example, the F6 panel is divided into 8 sections, A1, A2...A8, and are identified as F6/A1, F6/A2... F6/A8. Note that these secondary coordinates do not refer to the controls located in the *aft* portion of the flight deck.

Table III. - Hierarchical Task Listing
Shuttle Entry and Landing

HIERARCHICAL TASK LISTING
SHUTTLE ENTRY AND LANDING

El. Time	Alt Kft	Vrel Kfps (M)	Ny*	Nz*	Events/ CDR Task	Pilot Task	MS2 Task	Loc	Notes
EI -5:00	557	25.4	0.257	0	**01 BEGIN ENTRY SEGMENT (-24:09).**				
					01.01 MM304 Initiation.				
x	x	x	x	x	001 Type "OPS 304 PRO" into KYBD.			KYBD C2/A1	
					002 Check LVLH Attitude (0, 40, 0) on ADI.			ADI F6/A6 F8/A6	
x	x	x	x	x	003 Check FRCS MANF 1-4 closed.			FRCS O8/A5	
00:00	400	24.6	x	x	***Entry Interface.***				
					A01 *BEGIN PREENTRY PHASE (-4:36):*				
x	x	x	x	x	A01.01 Monitor alpha, qbar, phi, and drag-vel-range profile on ENT TRAJ 1 and Entry-Alpha Cue Card.	A01.01 Monitor alpha, qbar, phi, and drag-vel-range profile on ENT TRAJ 1 and Entry-Alpha Cue Card.	A01.01 Monitor alpha, qbar, phi, and drag-vel-range profile on ENT TRAJ 1 and Entry-Alpha Cue Card.	AMI F6/A2 CRTs 1, 2 & 3 F7/A1, A4, & A6	
					Auto elevon trim @ qbar=0.5.				
02:18	330	24.5	0.0643	0.257	A01.02 Monitor Entry DAP.	A01.02 Monitor Entry DAP.			
					001 Monitor elevons.	001 Monitor elevons.			
					002 Monitor body flap.	002 Monitor body flap.		SP1 F7/A3	
					003 Monitor RCS jet activity lights for off-nominal configuration/ usage.	003 Monitor RCS jet activity lights for off-nominal configuration/ usage.		RCS C2/A6	
03:24	298	24.5	0	0.772	*Aerosurface control @ qbar=2. Potential body flap saturation (M 24.6 - 22.5).*				

*(x=Missing Ny/Nz values due to LOS)

HIERARCHICAL TASK LISTING
SHUTTLE ENTRY AND LANDING

El. Time	Alt Kft	Vrel Kfps (M)	Ny*	Nz*	Events/ CDR Task	Pilot Task	MS2 Task	Loc	Notes
04:36	270	24.4	0	3.6	B01 ***BEGIN TEMP. CONTROL PHASE (–8:26):***				
04:51	265	24.4	*	4.89	B01.01 Monitor closed-loop guidance (D=3) initiation.	B01.01 Monitor closed-loop guidance (D=3) initiation.	B01.01 Monitor closed-loop guidance (D=3) initiation.	CRT 1 F7/A1	
04:52	265	24.4	*	5.66	*Roll jets deactivated @ qbar=10.*				
04:59	263	24.4	*	*	*First bank command.*				
					B01.02 Monitor direction, magnitude, and HDOT.	B01.02 Monitor direction, magnitude, and HDOT.	B01.02 Monitor direction, magnitude, and HDOT.	ADI F6/A6 F8/A6	
					B01.03 Monitor ROLL CMD/ ROLL REF:	B01.03 Monitor ROLL CMD/ ROLL REF:	B01.03 Monitor ROLL CMD/ ROLL REF:	CRTs 1, 2 F7/A1, A4	
					001 Monitor ADI display through TAEM Segment.	001 Monitor ADI display through TAEM Segment.	001 Monitor ADI display through TAEM Segment.	ADI F6/A6 F8/A6	
					002 Monitor ENT TRAJ display through TAEM Segment.	002 Monitor ENT TRAJ display through TAEM Segment.	002 Monitor ENT TRAJ display through TAEM Segment.	CRTs 1, 2 F7/A1, A4	
					003 Monitor AVVI & ENT TRAJ, establishing Hdot & Hdbldot trend to maintain or reconverge guidance.	003 Monitor AVVI & ENT TRAJ, establishing Hdot & Hdbldot trend to maintain or reconverge guidance.	003 Monitor AVVI & ENT TRAJ, establishing Hdot & Hdbldot trend to maintain or reconverge guidance.	AVVI F6/A4 F8/A3 CRT 1 F7/A1	
*	*	*	*	*	B01.04 Monitor continuously roll reversals & delta AZ on HSI & ENT TRAJ, now thru WP 1.	B01.04 Monitor continuously roll reversals & delta AZ on HSI & ENT TRAJ, now thru WP 1.	B01.04 Monitor continuously roll reversals & delta AZ on HSI & ENT TRAJ, now thru WP 1.	HSI F6/A7 F8/A7 CRT 1 F7/A1	
*	*	*	*	*	B01.05 Monitor drag-vel-range profile on ENT TRAJ 1.	B01.05 Monitor drag-vel-range profile on ENT TRAJ 1.	B01.05 Monitor drag-vel-range profile on ENT TRAJ 1.	CRT 1 F7/A1	
06:00	255	24.0	x	x	*Max surface temperature region (M 24-19.4). Drag profile within 0.5 fps2.*				

*(x=Missing Ny/Nz values due to LOS)

HIERARCHICAL TASK LISTING
SHUTTLE ENTRY AND LANDING

El. Time	Alt Kft	Vrel Kfps (M)	Ny*	Nz*	Events/ CDR Task	Pilot Task	MS2 Task	Loc	Notes
07:15	248	23.5	x	x	*Ny trim active @ qbar= 20. Four yaw jets available.*				
09:49	238	22.1	0	15.2	*Drag H update in NAV filter @ D=11.*				
					B01.06 Monitor H update with HSD.			CRTs 1, 2 F7/A1, A4	
11:51	228	20.6	*	20.3	*Pitch jets deactivated @ qbar= 40.*				
12:25	224	20.0	*	22.7	*MPS LO_2 Fill & Drain Valves open.*				
13:02	219	19.1	*	24.7	*RCS activity lights reconfigure @ qbar= 50.*				
					B01.07 Double Toggle if required.			KYBD C2/A1	
					001 Execute Item 6 EXEC twice.	B01.08 Monitor execution of Double Toggle.	B01.08 Monitor execution of Double Toggle.	CRTs 1, 2 F7/A1, A4	
*	*	*	*	*		B01.09 Check MPS/TVC Isol. Valves closed. 001 Inspect MPS/TVC valve status by using mirror or turning around to ensure that talkback indicates "CLOSED."		MPS/ TVC R4/A1	Panel R4 is out of the PLT's field of view. Therefore, the PLT must use a mirror, or physically turn around, to check that the valves are closed.
*	*	*	*	*	**C01 *BEGIN EQUILIBRIUM GLIDE PHASE (~2:48):***				
14:14	210	17.9	0.0643	30.4	C01.01 Monitor drag-vel-range profile on ENT TRAJ 1 & 2.	C01.01 Monitor drag-vel-range profile on ENT TRAJ 1 & 2.	C01.01 Monitor drag-vel-range profile on ENT TRAJ 1 & 2.	CRT 1&2 F7/A1 F7/A4	
15:34	195	15.7	*	40.9	C01.02 Monitor first roll reversal (delta Az=10.5 deg.).	C01.02 Monitor first roll reversal (delta Az=10.5 deg.).	C01.02 Monitor first roll reversal (delta Az=10.5 deg.).	ADI F6/A6 F8/A6 CRT 2 F7/A4	

*(x=Missing Ny/Nz values due to LOS)

HIERARCHICAL TASK LISTING
SHUTTLE ENTRY AND LANDING

El. Time	Alt Kft	Vrel Kfps (M)	Ny*	Nz*	Events/ CDR Task	Pilot Task	MS2 Task	Loc	Notes
15:50	193	15.3	0.129	43.5	**D01 *BEGIN CONSTANT DRAG PHASE (~1:40):*** D=33 fps^2				
16:00	190	15.0	x	x	D01.01 Monitor drag-vel-range profile on ENT TRAJ 2 & 3.	D01.01 Monitor drag-vel-range profile on ENT TRAJ 2 & 3.	D01.01 Monitor drag-vel-range profile on ENT TRAJ 2 & 3.	CRT 1 F7/A1	
17:23	181	12.2	0.193	46.3	*Alpha begins to ramp down.*				
17:30	180	12.0	*	45.8	D01.02 Select radiator flow: 001 RAD BYP VLV MODE (two) - AUTO		D01.03 Prompt CDR in selection of RAD and CNTRL LOOP from checklist.	RAD CTRL L1/A2	
					D01.04 Select CNTRL LOOP (two) -AUTO B(A).			CNTRL LOOP L1/A1	
*	*	*	*	*	**E01 *BEGIN TRANSITION PHASE (~6:39):***				
18:20	171	10.4	0.0643	47.6	E01.01 Monitor drag-vel-range profile on ENTRY TRAJ 4 & 5.	E01.01 Monitor drag-vel-range profile on ENTRY TRAJ 4 & 5.	E01.01 Monitor drag-vel-range profile on ENTRY TRAJ 4 & 5.	CRT 1&2 F7/A1 F7/A4	
*	*	*	*	*	E01.02 Monitor pitch, alpha, & alpha modulation separately on the ADI, AMI, & ENT TRAJ Display.	E01.02 Monitor pitch, alpha, & alpha modulation separately on the ADI, AMI, & ENT TRAJ Display.	E01.02 Monitor pitch, alpha, & alpha modulation separately on the ADI, AMI, & ENT TRAJ Display.	ADI F6/A6 F8/A6 AMI F6/A2 F8/A1 CRT 1&2 F7/A1 F7/A4	
*	*	*	*	*	*Alpha begins ramping down from 40-15deg.*				
18:33	168	10.0	*	47.9	E01.03 Check initial SPDBK deployment to 81%.	E01.03 Check initial SPDBK deployment to 81%.	E01.03 Check initial SPDBK deployment to 81%.	SPI F7/A3	
18:38	167	9.8	*	48.6	*Exit UHF communications blackout.*				

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HIERARCHICAL TASK LISTING
SHUTTLE ENTRY AND LANDING

El. Time	Alt Kft	Vrel Kfps (M)	Ny*	Nz*	Events/ CDR Task	Pilot Task	MS2 Task	Loc	Notes
19:48	154	7.9	0.193	45.8	*LG HYD. ISOL Valve 2 opens.*	E01.04 Verify LG HYD ISOL VLV 2 open.		LG HYD ISOL VLV R4/A1	PLT either looks in mirror or turns around to look at the R4 panel to verify this.
						001 Inspect HYD VLV status using mirror or turning around to ensure that its talkback indicates "OPEN."			
19:51	153	7.7	0.0643	45.6	*Earliest opportunity for runway redesignation.*				
20:10	150	7.2	-0.129	45.3	*Landing Site (EDW or KSC) TACAN Lock-on.*				
20:15	147	7.0	0.129	•	E01.05 Check TACAN status.	E01.05 Check TACAN status.	E01.05 Check TACAN status.	SPEC 50 Display CRT's 1, 2, & 3	May occur at a later point in time, after an on-board decision is made regarding TACAN information.
					001 Take TACAN to NAV at MCC call, else No-Comm Management.				
20:36	142	6.5	0.193	44.8	*Earliest opportunity for MCC state vector update.*				
21:52	122	5.0	0.0643	43.5	*Rudder becomes active.*				
					E01.06 Monitor aileron & rudder trim.	E01.06 Monitor aileron & rudder trim.	E01.06 Monitor aileron & rudder trim.	SPI F7/A3	
					001 Control roll trim manually, if required.			CRTs 1, 2 F7/A1, A4	
•	•	•	•	•	*Ammonia boiler activated.*				
•	•	•	•	•	E01.07 Deploy ADTA probes.		E01.07 Deploy ADTA probes.	ADTA C3/A6	ADTA probes are deployed by CDR or MS2, whomever is able to do it first.
					E01.08 Check Heat.	E01.08 Check Heat.	E01.08 Check Heat.		Heat position of the ADTA probe switch is used only if flying through visible moisture is anticipated.
22:43	107	4.0	0.0643	43.8	E01.09 Monitor Hdot.	E01.09 Monitor Hdot.	E01.09 Monitor Hdot.	AVVI F6/A4 F8/A3	
					001 Check Hdot < 500 fps.	001 Check Hdot < 500 fps.	001 Check Hdot < 500 fps.		

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HIERARCHICAL TASK LISTING
SHUTTLE ENTRY AND LANDING

El. Time	Alt Kft	Vrel Kfps (M)	Ny*	Nz*	Events/ CDR Task	Pilot Task	MS2 Task	Loc	Notes
22:43	107	3.4	0.0643	43.8	E01.10 <u>Check</u> ADTA probe deploy discrete.	E01.10 <u>Check</u> ADTA probe deploy discrete.		ADTA Switch F6/A1 F8/A4	
					001 <u>Switch</u> to L ADTA.	001 <u>Switch</u> to L ADTA.			
					002 <u>Switch</u> to R ADTA.	002 <u>Switch</u> to R ADTA.			
					003 <u>Switch</u> back to NAV.	003 <u>Switch</u> back to NAV.			
■	■	■	■	■	E01.11 <u>Monitor</u> the ADTA on SPEC 51.	E01.11 <u>Monitor</u> the ADTA on SPEC 51.		CRT's 1, 2, & 3 F7/A1, A4, & A6	
23:27	96	3.2	0.193	42.5	*SPDBK retracts to 65%.*				
					E01.12 <u>Monitor</u> SPDBK retraction.	E01.12 <u>Monitor</u> SPDBK retraction.	E01.12 <u>Monitor</u> SPDBK retraction.	SPI F7/A3	
23:39	93	3.0	0.257	40.9	*Elevon trim position to Zero.*				
					E01.13 <u>Take</u> ADTA to NAV and G&C on MCC call.	E01.14 <u>Monitor</u> CDR taking air data to NAV and G&C on MCC call.	E01.14 <u>Monitor</u> CDR taking air data to NAV and G&C on MCC call.	CRTs 1, 2 F7/A1, A4	
23:54	89	2.7	0.193	40.2	E01.15 <u>Power-up</u> HUD - ON.	E01.15 <u>Power-up</u> HUD - ON.		HUD	
						E01.16 <u>Check</u> APU's.		APU's F8/A8 R2/A2 R2/A3	
24:00	87	2.6	0.129	40.4	*Flash Evaporator OFF.*				
					Drag H update terminates.				
24:09	85	2.5	0.257	39.4	02 <u>BEGIN TAEM SEGMENT</u> (-5:00):				
■	■	■	■	■	02.01 <u>Monitor</u> Guidance Modes to MM305 on VERT SIT 1 display.	02.01 <u>Monitor</u> Guidance Modes to MM305 on VERT SIT 1 display.	02.01 <u>Monitor</u> Guidance Modes to MM305 on VERT SIT 1 display.	CRT 1 F7/A1	

*(x=Missing Ny/Nz values due to LOS)

El. Time	Alt Kft	Vrel Kfps (M)	Ny*	Nz*	Events/ CDR Task	Pilot Task	MS2 Task	Loc	Notes
24:09	85	2.5	0.257	39.4	A02 ***BEGIN ACQUISITION PHASE (–2:51):***				
					BEGIN ARC SUBPHASE:				
*	*	*	*	*	A02.01 Assess current energy situation on the VERT SIT 1 plot & E/W scale.	A02.02 Monitor initiation of TAEM Guidance.	A02.02 Monitor initiation of TAEM Guidance.	CRT 1 F7/A6	Adjustments to TAEM Guidance primarily consist of calls from MCC.
					A02.03 Check SPDBKs to 65%.	A02.03 Check SPDBKs to 65%.	A02.03 Check SPDBKs to 65%.	SPI F7/A3	
*	*	*	*	*	***BEGIN LINE SUBPHASE:***				
					A02.04 Assess energy & trajectory by plot & energy bug.	A02.05 Monitor continuously Energy & Trajectory on VERT SITs.	A02.05 Monitor continuously Energy & Trajectory on VERT SITs.	CRT 1&2 F7/A6 F7/A4	
*	*	*	*	*	A02.06 Monitor successively the following dedicated displays: • AVVI • AMI • HSI -- Glideslope • HSD • VSD • SPI	A02.06 Monitor successively the following dedicated displays: • AVVI • AMI • HSI -- Glideslope • HSD • VSD • SPI	A02.06 Monitor successively the following dedicated displays: • AVVI • AMI • HSD • VSD • Warning Light Panel • SPI	AVVI F6/A4 F8/A4 AMI F6/A2 F8/A1 HSI F6/A7 F8/A7 HSD (CRT 3) F7/A6 VSD (CRT 1) F7/A1 SPI F7/A3 Warning Panel F7/A2	MS2 monitors the AVVI on the F6 panel and the AMI on the F8 panel. Monitoring of all displays listed here is not unique to this Phase. Rather, they are being scanned successively during the entire E/L procedure. Since monitoring of these displays is so frequent and nonsequential, it is not possible to list every occurrence.

*(x=Missing Ny/Nz values due to LOS)

HIERARCHICAL TASK LISTING
SHUTTLE ENTRY AND LANDING

El. Time	Alt Kft	Vrel Kfps (M)	Ny*	Nz*	Events/ CDR Task	Pilot Task	MS2 Task	Loc	Notes
24:09	85	2.5	0.257	39.4	A02.07 <u>Monitor</u> SPEC 50 on CRT 1. 001 <u>Activate</u> SPEC 50 on CRT 1 with entry on KYBD 1.	A02.07 <u>Monitor</u> SPEC 50 on CRT 2. 001 <u>Activate</u> SPEC 50 on CRT 2 with entry on KYBD 2.	A02.07 <u>Monitor</u> SPEC 50 on CRT 1 or 2.	CRT 1 F7/A1 CRT 2 F7/A4 KYBD 1 & 2 C2	
24:20	83	2.4	-0.0643	40.4	*Fuselage vents open.*				
x	x	2.0	x	x	A02.08 <u>Ensure</u> ADTA to G&C.			CRT 1 F7/A1	
25:50	50	1.2	0.45	30.4	*Auto aileron trim deactivated in CSS.*				
26:21	48	0.9	0.579	32.4	*Yaw jets deactivated @ M=1.*				
26:27	48	0.9	0.257	32.2	*SPDBK begins modulating for energy (A/S) @ M=0.95.*				
					A02.09 <u>Verify</u> SPDBK modulation on HUD and SPI.	A02.09 <u>Verify</u> SPDBK modulation on HUD and SPI.	A02.09 <u>Verify</u> SPDBK modulation on HUD and SPI.	HUD SPI F7/A3	
					Elevon trim position to 4 ° down.				
					A02.10 <u>Verify</u> on SPI elevon position to 4° down.	A02.10 <u>Verify</u> on SPI elevon position to 4° down.	A02.10 <u>Verify</u> on SPI elevon position to 4° down.	SPI F7/A3	
x	x	x	x	x	A02.11 <u>Begin</u> CSS: P, R/Y. 001 <u>Depress</u> the P and R/Y CSS PBI's. 002 <u>Verify</u> that white lights on switches have illuminated, indicating CSS has been engaged.			RHC P, R/Y F2	
26:27	48	0.9	0.257	32.2		A02.12 <u>Check</u> SPDBK CMD vs. POS. 001 <u>Compare</u> CMD pointer versus POS pointer on SPI and HUD SPDBK indicators.		SPI F7/A3 HUD	

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El. Time	Alt Kft	Vrel Kfps (M)	Ny*	Nz*	Events/ CDR Task	Pilot Task	MS2 Task	Loc	Notes
26:27	48	0.9	0.257	32.2	A02.13 <u>Check</u> to ensure that NWS switch is in the GPC position.	A02.14 <u>Verify</u> R FLT CNTRL PWR- ON. 001 <u>Look</u> to confirm that the FLT CNTRL switch is in the ON position.		R FLT CNTRL F8/A8 NWS L2/A2	NWS to GPC is usually done prior to entry, with this "check" being a verification. R FLT CNTRL PWR is turned on prior to deorbit burn TIG. Verification at this point is done as a safeguard.
27:00	40	0.8	0.322	29.3	**B02** ***BEGIN HEADING ALIGNMENT PHASE (~1:50):*** *HAC interception @ WP1.* B02.01 <u>Initiate</u> RHC maneuvers/ inputs to follow guidance commands and confirm reaction.			RHC	
*	*	*	*	*	B02.02 <u>Verify</u> HAC intercept by confirming 3 things: 001 <u>Confirm</u> HUD shows no errors. 002 <u>Confirm</u> ADI shows no errors. 003 <u>Confirm</u> SPEC 50 shows proper flight path.	B02.02 <u>Verify</u> HAC intercept by confirming 3 things: 001 <u>Confirm</u> HUD shows no errors. 002 <u>Confirm</u> ADI shows no errors. 003 <u>Confirm</u> SPEC 50 shows proper flight path.		HUD ADI F6/A6 F8/A6 CRT 1&2 F7/A1 F7/A4	
27:00	40	0.8	0.322	29.3	*LG HYD ISOL VLV 1 opens.*	B02.03 <u>Verify</u> LG HYD ISOL VLV 1 open. 001 <u>Inspect</u> LG HYD ISOL VLV status using mirror or turning around to see that its talkbacks indicate "OPEN."		LG HYD ISOL VLV R4	PLT either looks in mirror to verify this or turns around to look at the R4 panel.

*(x=Missing Ny/Nz values due to LOS)

HIERARCHICAL TASK LISTING
SHUTTLE ENTRY AND LANDING

El. Time	Alt Kft	Vrel Kfps (M)	Ny*	Nz*	Events/ CDR Task	Pilot Task	MS2 Task	Loc	Notes
27:00	40	0.8	0.322	29.3	B02.04 <u>Monitor</u> SPEC 50 display on CRT 1.	B02.05 <u>Monitor</u> SPEC 50 on CRT 2.		CRT1&2 F7/A1 F7/A4	
					001 <u>Confirm</u> SPEC 50 information on ADI & HUD.	001 <u>Confirm</u> SPEC 50 information on ADI & HUD.		ADI F6/A6 F8/A6 HUD	
					B02.06 <u>Follow</u> guidance, correcting for errors.	B02.06 <u>Follow</u> guidance, correcting for errors.		RHC	
x	x	x	x	x	B02.07 <u>Crosscheck</u> HSI for NAV information.	B02.07 <u>Crosscheck</u> HSI for NAV information.		HSI F6/A7 F8/A7	
					001 <u>Check</u> the Magnetic Heading.	001 <u>Check</u> the Magnetic Heading.			
					002 <u>Check</u> the Course Deviation reading.	002 <u>Check</u> the Course Deviation reading.			
					003 <u>Check</u> Glide Slope reading.	003 <u>Check</u> Glide Slope reading.			
28:42	15	0.6	0.257	38.4	***Start Landing Comm. Protocol (silent cockpit except for callouts listed below and problems).***	***Start Landing Comm. Protocol (silent cockpit except for callouts listed below and problems).***	***Start Landing Comm. Protocol (silent cockpit except for callouts listed below and problems).***		
x	x	x	x	x	B02.08 <u>Obtain</u> visual of APILs by looking out the side windows (W1&W2 or W5&W6, depending on approach).	B02.08 <u>Obtain</u> visual of APILs by looking out the side windows (W1&W2 or W5&W6, depending on approach).		Out Windows 1& 2 *or* 5& 6	
28:42	15	0.6	0.257	38.4		B02.09 <u>Check</u> MLS acquisition (G-50, TACAN ratios & residuals blank).	B02.09 <u>Check</u> MLS acquisition (G-50, TACAN ratios & residuals blank).	CRT 1&2 F7/A1 F7/A4	
x	x	x	x	x			B02.10 <u>Call</u> "MLS."	Call	

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HIERARCHICAL TASK LISTING
SHUTTLE ENTRY AND LANDING

El. Time	Alt Kft	Vrel Kfps (M)	Ny*	Nz*	Events/ CDR Task	Pilot Task	MS2 Task	Loc	Notes
28:50	14	0.6	0	38.6	**C02 *BEGIN PREFINAL PHASE (–0:19):***				
•	•	•	•	•	*Transition from HAC to OGS.*				
					C02.01 Roll wings level.			RHC	
					001 Initiate RHC inputs.			ADI F6/A6	
					002 Monitor successively Guidance Needles (ADI), HUD, HSI, CRT 1, Out Window (Perceptual Cues).			HUD HSI F6/A7 CRT 1 F7/A1 Out Window	
•	•	•	•	•	C02.02 Monitor any updates or changes in wind conditions.				
					001 Listen for MCC updates on wind conditions.			MCC call	
					002 Watch (be alert) for any changes in wind conditions.			HUD Out Window	
•	•	•	•	•	*HSI reconfigures for the A/L Segment.*				
					C02.03 Verify Reconfiguration of HSI.	C02.03 Verify Reconfiguration of HSI.		HSI's F6/A7 F8/A7	
					001 Check that HSI's Primary and Secondary Bearing pointers have converged, pointing toward runway.	001 Check that HSI's Primary and Secondary Bearing pointers have converged, pointing toward runway.			
28:50	14	0.6	0	38.6	C02.04 Check PAPI's & HUD overlay on runway. HUD MODE-DCLT as required.	C02.04 Check PAPI's & HUD overlay on runway. HUD MODE-DCLT as required.		PAPIs Out Window HUD DCLT F6/A3 F8/A2	

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HIERARCHICAL TASK LISTING
SHUTTLE ENTRY AND LANDING

El. Time	Alt Kft	Vrel Kfps (M)	Ny*	Nz*	Events/ CDR Task	Pilot Task	MS2 Task	Loc	Notes
29:09	10	0.6	0	37.3	03 <u>BEGIN APPROACH & LAND SEGMENT</u> (≈1:50): *GNC SYS SUMM display on CRT 2.* 03.04 <u>Call-up</u> GNC SYS SUMM on CRT 2 with KYBD entry.	03.01 <u>Call</u> "A/L" flash on HUD.	03.02 <u>Call</u> "A/L" flash on VERT SIT 2. 03.03 <u>Monitor</u> displays for overall vehicle configuration, fault messages, problems throughout A/L.	HUD CRT 2 F7/A4 Warning Panel F7/A2 SPI F7/A3 CRT 1, 2 & 3 F7/A1, A4 & A6 KYBD C2/A1	Calling up GNC SYS SUMM is an optional task. It depends on the CDRs preference.
x	x	x	x	x	***A03 BEGIN TRAJECTORY CAPTURE PHASE:*** *Body Flap to trail.*				
x	x	x	x	x	A03.01 <u>Verify</u> visually on SPI that BF pointer moves to ≈ 37%.	A03.01 <u>Verify</u> visually on SPI that BF pointer moves to ≈37%.	A03.01 <u>Verify</u> visually on SPI that BF pointer moves to ≈37%.	SPI F7/A3	
29:09	10	0.6	0	37.3	A03.02 <u>Execute</u> Control Inputs to capture OGS, targeting vehicle for aimpoint & PAPI's. 001 <u>Push</u> forward on RHC to obtain correct pitch.		A03.03 <u>Check</u> body flap to trail. A03.04 <u>Check</u> A/L on VERT SIT. A03.05 <u>Call</u>: "APPROACH & LAND, BF TRAIL."	RHC SPI F7/A3 CRT 2 F7/A4 Call	Due to handling characteristics of the Orbiter, control inputs on the RHC are very slight. Therefore, the "Push" listed here would be a very small forward input.
29:09	10	0.6	0	37.3	***B03 BEGIN OUTER/STEEP GLIDE SLOPE PHASE*** (≈0:43):				

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El. Time	Alt Kft	Vrel Kfps (M)	Ny*	Nz*	Events/ CDR Task	Pilot Task	MS2 Task	Loc	Notes
29:09	10	0.6	0	37.3	B03.01 Compare HUD runway overlay to actual runway to establish NAV error. • *If overlay is good :* 001 Select HUD declutter level 1 or 2. 002 Follow NAV guidance diamond. • *If overlay indicates excessive NAV error :* 001 Declutter HUD. 002 Maintain glideslope by placing velocity vector on aim point (next to PAPI's).	B03.01 Compare HUD runway overlay to actual runway to establish NAV error. • *If overlay is good :* 001 Select HUD declutter level 1 or 2. 002 Follow NAV guidance diamond. • *If overlay indicates excessive NAV error :* 001 Declutter HUD. 002 Maintain glideslope by placing velocity vector on aim point (next to PAPI's).		HUDs HUD Switch RHC	
29:09	10	0.6	0	37.3	B03.02 Execute pitch adjustment as needed to maintain glide slope/KEAS balance.	B03.03 Monitor airspeed for 290 KEAS. B03.04 Monitor outside PAPI lights for 19° glide slope.		RHC HUD PAPIs Out Window	
					SPDBK adjusts with pitch.		B03.05 Monitor SPDBK adjustment as pitch is altered.	SPI F7/A3	
*	*	*	*	*	B03.06 Call 2 red & 2 white lights.			Out Window	
29:09	(7)	0.6	0	37.3		B03.07 Call airspeed & altitude.		HUD	
29:30	5	0.5	-0.0643	29.3	*Radar altimeter activated.*				
					B03.08 Verify RADAR ALT Scale becomes active on HUD.	B03.08 Verify RADAR ALT Scale becomes active on HUD.		HUD	

*(x=Missing Ny/Nz values due to LOS)

HIERARCHICAL TASK LISTING
SHUTTLE ENTRY AND LANDING

El. Time	Alt Kft	Vrel Kfps (M)	Ny*	Nz*	Events/ CDR Task	Pilot Task	MS2 Task	Loc	Notes
							B03.09 <u>Verify</u> RADAR ALT is active on AVVI.	AVVI F6/A4	
29:30	5	0.5	-0.0643	29.3		B03.10 <u>Compare</u> RADAR ALT 1 vs. 2.		RAD ALT F8/A8 O8/A1	
						B03.11 <u>Call</u>: "RADAR ALTIMETER, 1 & 2 CHECK GOOD."		Call	
						B03.12 <u>Call</u> airspeed & altitude.		Call HUD	
•	4	•	•	•		B03.13 <u>Call</u> "4K FEET."		Call HUD	
29:46	3	0.5	0.45	32.7		B03.14 <u>Call</u> "3K FEET."		Call HUD	
•	•	•	•	•	*Smart SPDBKs retract to new value.*	B03.15 <u>Check</u> SPDBK CMD %.		SPI F7/A3	
						001 <u>Verify</u> SPDBK value with value on Cue Card (15-25%).			
						B03.16 <u>Call</u> "BOARDS ____%."		Call	
•	•	•	•	•	B03.17 <u>Monitor</u> progression of HUD velocity vector tri-angles for onset of Preflare.	B03.17 <u>Monitor</u> progression of HUD velocity vector triangles for onset of Preflare.		HUD	
29:52	2	0.5	0.45	32.2	**C03 *BEGIN PREFLARE PHASE (~0:14):***				
•	•	•	•	•	C03.01 <u>Call</u>: "PREFLARE, ARM GEAR."	C03.02 <u>Call</u>: "2K FEET, PREFLARE NEXT."		Calls HUD	
•	•	•	•	•	C03.03 <u>Arm</u> landing gear.	C03.03 <u>Arm</u> landing gear.			
					001 <u>Depress</u> LG ARM PBI.	001 <u>Depress</u> LG ARM PBI.		HUD	
					002 <u>Verify</u> that yellow light is illuminated on PBI indicating gear are armed.	002 <u>Verify</u> that yellow light is illuminated on PBI indicating gear are armed.		GEAR ARM F6/A5 F8/A5	

*(x=Missing Ny/Nz values due to LOS)

HIERARCHICAL TASK LISTING
SHUTTLE ENTRY AND LANDING

El. Time	Alt Kft	Vrel Kfps (M)	Ny*	Nz*	Events/ CDR Task	Pilot Task	MS2 Task	Loc	Notes
29:52	2	0.5	0.45	32.2	C03.04 <u>Initiate</u> Preflare maneuver and transition onto Ball/ Bar. 001 <u>Pitch-up</u> with RHC to establish constant-g rotation and IGS *or* proper Ball/ Bar relationship.	C03.05 <u>Call</u>: "GEAR ARE ARMED."		RHC Call	
x	x	x	x	x	C03.06 <u>Monitor</u> continuation of Preflare on HUD. 001 <u>Monitor</u> progression of velocity vector triangles. 002 <u>Ensure</u> reference pointer is just below horizon. 003 <u>Monitor</u> visual references out window.			HUD Out Windows	
x	1.5	x	x	x			C03.07 <u>Recheck</u> SPDBK for correct value.	SPI F7/A3	MS2 is probably checking SPDBK for a "ballpark" value, since at this point it is difficult to obtain an exact SPDBK value. (The "correct" value is based upon computer model estimates which may not take into consideration the most current wind, energy, conditions, etc.)
29:52	1.0	0.5	x	32.2		C03.08 <u>Call</u>: "1K FEET, ____ KNOTS ____" (knots called are max KEAS in preflare).		Call HUD	
29:52	500f	0.5	x	32.2		C03.09 <u>Call</u>: "500 FEET, A/S ____."	C03.10 <u>Check</u> SPDBK %.	Call HUD SPI F7/A3	
30:06	400f	0.5	-0.643	30.6	D03 ***BEGIN INNER/ SHALLOW GLIDE SLOPE PHASE (~0:22):***				
x	x	x	x	x	D03.01 <u>Move</u> RHC to acquire IGS (indicated by ball/bar relationship).	D03.02 <u>Call</u>: "400 FEET, A/S ____."		RHC Call HUD	

*(x=Missing Ny/Nz values due to LOS)

HIERARCHICAL TASK LISTING
SHUTTLE ENTRY AND LANDING

El. Time	Alt Kft	Vrel Kfps (M)	Ny*	Nz*	Events/ CDR Task	Pilot Task	MS2 Task	Loc	Notes
30:06	400f	0.5	-0.643	30.6	D03.03 <u>Monitor</u> out-the-window ball /bar.			Out Window	
					001 <u>Adjust</u> pitch as needed to achieve & maintain 1.0-1.5 deg. IGS. (Ball on top of bar yields better 1.0 deg. manual GS).			RHC	
					002 <u>Line-up</u> ball so it appears to be moving along light bar.				
30:06	300f	0.5	-0.643	30.6	D03.04 <u>Call</u>: "GEAR DOWN"		D03.05 <u>Check</u> SPDBK setting.	Call SPI F7/A3	
					D03.06 <u>Depress</u> GR DN button.	D03.06 <u>Depress</u> GR DN button.		GEAR DN F6/A5 F8/A5	CDR & PLT may both push GR DN button; however, in most cases, the PLT will depress the gear-down button rather than the CDR.
30:06	300f	0.5	-0.643	30.6	D03.07 <u>Call</u>: "GEAR COMING" (Flashing symbology '/GR//' occurs on HUD).	D03.07 <u>Call</u>: "GEAR COMING" (Flashing symbology '/GR//' occurs on HUD).		Call HUD HUD	
						D03.08 <u>Check</u> that gear indicates DOWN--'GR-DN' symbology appears on HUD.	D03.08 <u>Check</u> that Gear indicates DOWN--'DN'--appears on all 3 LG talkbacks.	GEAR DN F8/A5	
▪	▪	▪	▪	▪	D03.09 <u>Stabilize</u> Orbiter on IGS (at this point CDR is utilizing visual cues outside to stabilize Orbiter).	D03.10 <u>Call</u>: "GEAR IS DOWN."	D03.11 <u>Call</u>: "BOARDS ___%, GEAR IS DOWN."	RHC SPI Calls F7/A3	
▪	▪	▪	▪	▪	D03.12 <u>Correct</u> any lateral errors.			RHC	
▪	▪	▪	▪	▪					

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HIERARCHICAL TASK LISTING
SHUTTLE ENTRY AND LANDING

El. Time	Alt Kft	Vrel Kfps (M)	Ny*	Nz*	Events/ CDR Task	Pilot Task	MS2 Task	Loc	Notes
30:06	300f	0.5	-0.643	30.6		D03.13 Call: "300 FEET, ____ KT." (PLT makes subsequent altitude and KEAS calls in a steady cadence, from 300 - 5 ft.)		Call HUD	
30:06	200f	0.5	-0.643	30.6		D03.14 Call: "200 ft., ____ KT."		Call	
30:06	100f	0.5	-0.643	30.6		D03.15 Call: "100 ft., ____ KT."		Call	
x	70f	x	x	x		D03.16 Call: "70 ft., ____ KT."		Call	
30:16	60f	0.4	1.35	45.8	***E03 BEGIN FINAL FLARE (~0:12)***			RHC	
					E03.01 Initiate Final Flare with pitch-up RHC command.			HUD	
					E03.03 Monitor Hdot (sink rate) & alpha (pitch angle), utilizing visual cues out window of Orbiter.	E02.02 Call: "60 ft., ____ KT."			
30:16	60f	0.4	1.35	45.8	E03.04 Align upper limb of HUD velocity vector tangent to & just below horizon line as vehicle crosses threshold, producing approx. 2-3 ft/s sink rate.			HUD/ Out Window	Final Flare is most likely performed using a depth perception cue rather than the HUD flight path marker.
					E03.05 Fly to EAS, not to "touchdown spot."			HUD	
								HUD	
x	50f	x	x	x		E03.06 Call: "50 ft., ____ KT."		Call HUD	

*(x=Missing Ny/Nz values due to LOS)

HIERARCHICAL TASK LISTING
SHUTTLE ENTRY AND LANDING

El. Time	Alt Kft	Vrel Kfps (M)	Ny*	Nz*	Events/ CDR Task	Pilot Task	MS2 Task	Loc	Notes
30:16	40f	0.4	1.35	45.8		E03.07 Call: "40 ft., ____ KT."		Call	
"	30f	"	"	"		E03.08 Call: "30 ft., ____ KT."		Call	
30:16	20f	0.4	1.35	45.8	*Runway Threshold crossed. (Approx. 15 Ft. ALT.)*	E03.09 Call: "20 ft., ____ KT."		Call	
"	10f	"	"	"		E03.10 Call: "10 ft., ____ KT."		Call	
30:16	5f	0.4	1.35	45.8	E03.11 Execute RHC inputs to null errors caused by gusts, turbulence, ground effects.	E03.12 Call: "5 ft., ____ KT."		RHC Call	
30:28	TD	195 KT	-0.193	35.8	**F03 *BEGIN TOUCH-DOWN & ROLLOUT PHASE (~0:31):***				
"	"	"	"	"	F03.01 Control drift with rudder. 001 Apply heel pressure to rudder pedals as needed. F03.03 Control bank with Lateral RHC (ailerons).	F03.02 Call: "TOUCHDOWN, BOARDS OPEN."		RHC/ Rudder Pedals Call HUD	
"	"	"	"	"	F03.04 Select Manual SPDBK. 001 Depress SPDBK Takeover Switch. 002 Pull back SPDBK/ Thrust Control Lever as needed.	F03.05 Check HUD display for WOWLON: 001 Observe Pitch Bars present and WOWLON flag. 002 Observe that Velocity Vector disappears (Cross-wind may delay this).	F03.06 Check SPDBK opening to 100%.	SPDBK Lever L/2 HUD SPI F7/A3	
"	"	"	"	"	*HUD reconfigures.*	F03.07 Call: "WOW CONFIRMED."		Call HUD	

*(x=Missing Ny/Nz values due to LOS)

El. Time	Alt Kft	Vrel Kfps (M)	Ny*	Nz*	Events/ CDR Task	Pilot Task	MS2 Task	Loc	Notes
30:28	"	185 KT	-0.193	35.8		F03.08 <u>Call</u>: "185, DEROTATE" (Even without WOWLON).		Call HUD	
30:28	De-rota-tion	185 KT	-0.193	35.8	F03.09 <u>Derotate</u> at 2-3 deg/s.	F03.10 <u>Monitor</u> pitch needle on ADI to observe Pitch Rate.		RHC ADI F8/A6	Derotating 2-3 deg/s is a demanding task and very important for a safe landing -- (i.e., too slow or too fast would have adverse effects).
						001 <u>Call</u>: "PITCH RATE ____" (Repeats rate at regular cadence during derotation).		Call	
"	"	"	"	"		F03.11 <u>Call</u> airspeed continuously at 10-KT increments through WONG until braking initiated.		Call HUD	
"	"	"	"	"	F03.12 <u>Check</u> Auto Load Relief. 001 <u>Ensure</u> that PITCH PBI has transitioned from CSS to AUTO to confirm that flight control is up-moded to Auto Pitch.	F03.12 <u>Check</u> Auto Load Relief. 001 <u>Ensure</u> that PITCH PBI has transitioned from CSS to AUTO to confirm that flight control is up-moded to Auto Pitch.	F03.12 <u>Check</u> Auto Load Relief. 001 <u>Watch</u> Elevon needles on SPI going down. 002 <u>Call</u> "LOAD RELIEF" *or* "NO LOAD RELIEF."	CSS/Auto Pitch F2 & F4 SPI F7/A3	
30:37	0	165 KT	-0.193	33.7	F03.13 <u>Maintain/correct</u> to centerline with NWS. 001 <u>Maintain</u> proper heel pressure on rudder pedals to keep on centerline.	F03.14 <u>Back-up</u> WOW flag. 001 <u>Place</u> SRB SEP or ET SEP switch to AUTO/ MANUAL. 002 <u>Depress</u> the SRB or ET SEP PB.		Rudder Pedals HUD SRB & ET C3/A4	
						F03.15 <u>Call</u>: "WOW SET."		Call	
"	"	"	"	"		F03.16 <u>Verify</u> LG HYD ISOL VLV 3 Open using mirror.		R4	

*(x=Missing Ny/Nz values due to LOS)

HIERARCHICAL TASK LISTING
SHUTTLE ENTRY AND LANDING

El. Time	Alt Kft	Vrel Kfps (M)	Ny*	Nz*	Events/ CDR Task	Pilot Task	MS2 Task	Loc	Notes
30:37	0	165 KT	-0.193	33.7			F03.17 Check that Elevons Down.	Call SPI F7/A3	
							F03.18 Check that NWS FAIL and Anti-skid FAIL lights off.	NWS/ Anti-skid F3	
30:47	Mid-Field	165 KT	0.515	32.2	F03.19 Check GS and DECEL on HUD.	F03.20 Call: "MIDFIELD."		HUD Call	
30:47		140 KT	0.515	32.2	F03.21 Initiate braking at runway midpoint or 140 KT, whichever occurs first.			Rudder Pedals	CDR and PLT monitor KT and Braking (FPS^2) on HUD.
					001 Brake at 8-10 FPS^2 by applying proper toe pressure on pedals.				
					002 Monitor braking rate on HUD or on AMI (Accel. Tape).			HUD AMI F6/A2	
30:47	5K ft re-mai-ning	140 KT	0.515	32.2	F03.22 Initiate MAX braking (if GS > 140 KT).	F03.23 Call: "5K FT. REMAINING."		BRK Call HUD	
30:47		140 130 120 110 100 90 80 70 60 50	0.515	32.2		F03.24 Call: "____ KT., ____ (DECEL Reading)."		Call HUD	KT are read by the PLT during deceleration, in intervals of 10, until wheel stop.
30:51		40	"	"	F03.25 Reduce braking to < 6 fps^2.	F03.26 Call: "40 KT., EASE OFF [Brakes]."		Rudder Pedals Call HUD	
30:59		0	0.257	31.7	F03.27 Report "WHEELS STOPPED" to MCC.			Call	

*(x=Missing Ny/Nz values due to LOS)

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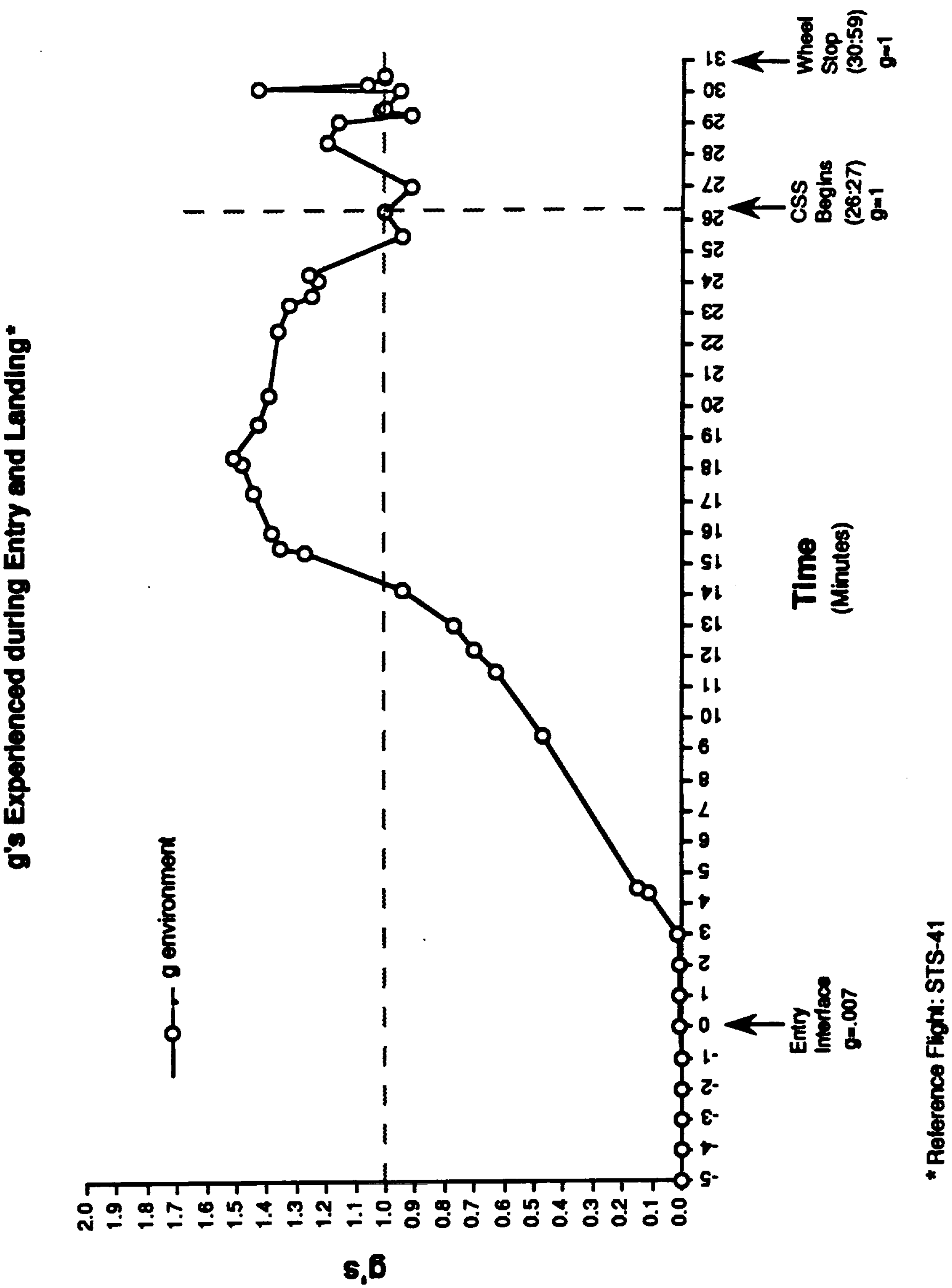
APPENDIX A

G's Experienced During Entry and Landing



APPENDIX B

Comments on Entry/Landing Provided by Crewmembers

- From Entry Interface minus 5 minutes the commander (CDR), pilot (PLT) and mission specialist 2 (MS2) *continuously* monitor all relevant instrumentation (e.g., altitude/vertical velocity indicator (AVVI), alpha mach indicator (AMI), horizontal situation indicator (HSI), attitude direction indicator (ADI), surface position indicator (SPI), entry trajectory (ENT TRAJ), horizontal situation display (SPEC 50)).

  * It was not feasible to indicate when all monitoring tasks were taking place, since this is an ongoing task from entry interface to wheel stop. We, therefore, elected to include intermittently the most frequently monitored controls as an indication that this activity is still ongoing.

- Regarding MS2 functions: In general, since MS2 can see both sides of cockpit, he/she will call out and monitor all events. On a nominal entry, each of the three crewmembers will verify the major events.
- V_{rel} Kfps (M) for Entry and Landing is dependent on trajectory and will be slightly different for each flight.
- B01.07: 001 "Double Toggle" (elapsed time 13:02). This procedure will be deleted when new instrumentation and software are introduced to the Orbiters.
- A03.02 (Elapsed Time 29:09). Executing control inputs to capture outer glide slope (OGS) should not, in a nominal situation, require a pitchover and roll-out. Rather, it should be a smooth maneuver from heading alignment cone (HAC) intercept to arrive established OGS. Commander is constantly flying both axes, and the physical environment is always approximately 1g.
- During the "Final Flare Initiation" (D03.17: elapsed time 30:16) of E/L, the task is a closed-loop command, made smoothly, not an open-loop command. During training sessions in the SMS, however, it is considered open-loop.
- D03.20 "Alignment of heads-up display (HUD) Velocity Vector" (elapsed time 30:16). The method of aligning the velocity vector is a *technique* task. No specific method is universal to all CDRs and PLTs. In one CDR's opinion, to do it well, you should not use the HUD flight path markers. Rather, it is an "outside-view depth perception" maneuver entirely.

- With regard to the rudder pedals for steering, no one is allowed to touch them until main gear touchdown. Also, the braking function of the rudder pedals is not permitted to be used until midfield has been reached.
- Because of the handling characteristics of the Orbiter, control inputs on the RHC are very slight. For example, the "Push forward on RHC" listed in A03.02: 001 would be a very small forward input.
- During preflare phase (onset at elapsed time 29:52) and following, crewmembers are probably checking speedbrake (SPDBK) for a "ballpark" value. During that time, it has a "mind of its own." Additionally, the "correct" SPDBK values that are being verified are based on computer model estimates, which may not have utilized the most current wind conditions or energy state, etc.

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Albert W. Holland (NASA/JSC)
Stephen T. Vander Ark (KRUG)

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NASA/JSC
Behavior and Performance Lab
Houston, TX 77058

KRUG Life Sciences
Behavior and Performance Lab
Houston, TX 77058

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13. ABSTRACT *(Maximum 200 words)*
The Task Analysis of Shuttle Entry and Landing (E/L) Activities documents all tasks required to land the Orbiter following an STS mission. In addition to analysis of tasks performed, task conditions are described including estimated time for completion, altitude, relative velocity, normal and lateral acceleration, location of controls operated or monitored, and level of g's experienced. This analysis precedes further investigations into potential effects of zero g on piloting capabilities for landing the Orbiter following long-duration missions. This includes, but is not limited to, researching the effects of extended duration missions on piloting capabilities. Four primary constraints of the analysis must be clarified: (1) the analysis depicts E/L in a static manner; whereas the actual process is dynamic; (2) the task analysis was limited to a paper analysis, since it was not feasible to conduct research in the actual setting (i.e., observing or filming during an actual E/L); (3) the tasks included are those required for E/L during nominal, daylight conditions; and (4) certain E/L tasks will vary according to the flying style of each commander.

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