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Mission Operations

Robert D. Nordeen
The Johns Hopkins University
Applied Physics Laboratory
(301) 953-5830
robert.nordeen@jhuapl.edu

Topics of Discussion

- **Requirements**
- **Operations Concept**
- **Operations Phases**
- **Staffing**
- **Interfaces**
- **Documentation**

Requirements

- **Ground operations**
  - **Spacecraft operated by APL Mission Operations Team located at APL Mission Operations Center (MOC)**
  - **Instruments operated by Instrument Teams located at Instrument Payload Operations Centers (POCs)**
  - **APL MOC provides command and telemetry data gateway to the spacecraft**
  - **MOT responsible for spacecraft bus operations planning, control and performance assessment**
  - **Instrument Teams responsible for instrument operations planning, control and performance assessment**
  - **One spacecraft contact each day, during day shift (nominally 10 minutes duration)**

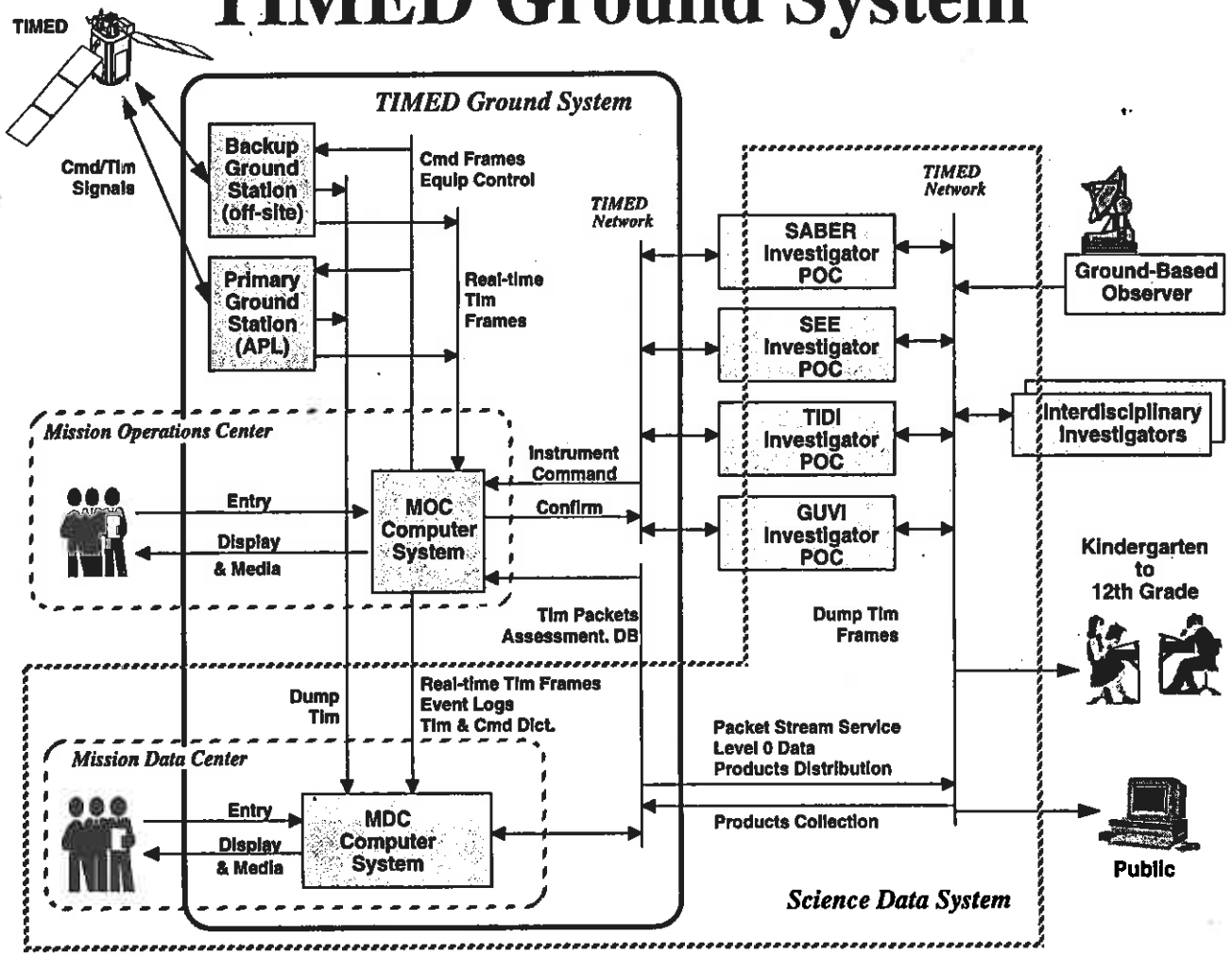
Operations Concept

- **Simplified spacecraft control from ground**
  - **Power management not required**
  - **Continuous nadir-pointing orientation**
  - **On-board tracking and time recovery**
    - » **Autonomous transmitter control over ground stations**
  - **Event-driven experiment data collection**
  - **Decoupled instrument operations**
- **Small Mission Operations Team (MOT)**
  - **One shift per day staffing**
  - **Well-trained operational staff**
- **Data recovery requirements (95% of SSR data) are not severe**

Operations Concept

- **Tracking and Orbit Determination**
  - **Spacecraft GPS Navigation System (GNS) produces on-board navigation data (position, velocity and time) and broadcasts to other spacecraft subsystems, and to ground**
  - **GNS also generates ground antenna pointing data (in the format of NORAD two-line element sets)**
  - **NORAD ground tracking is only ground tracking employed (and only as a backup to the spacecraft generated data)**

TIMED Ground System



PJG, Rev g, 10-14-97

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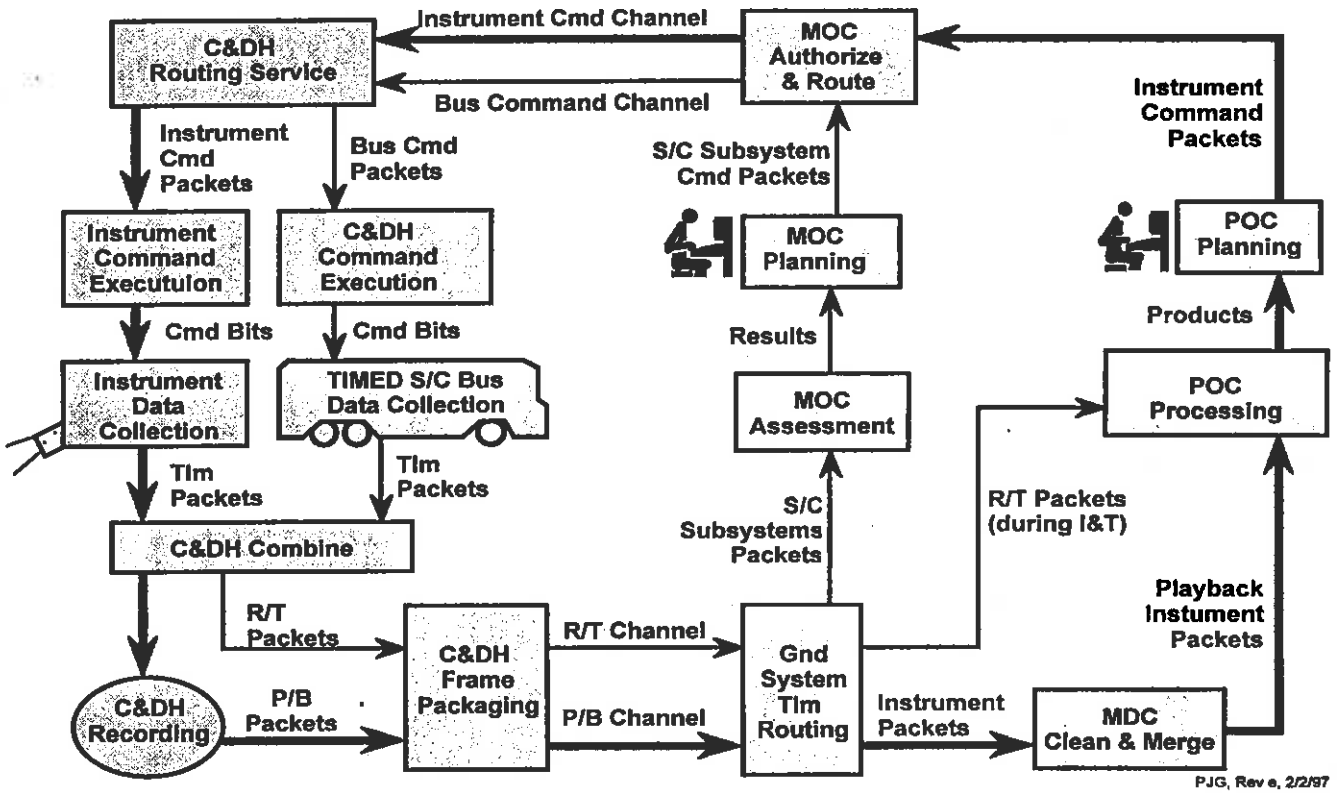
TIMED Mission Data Flow



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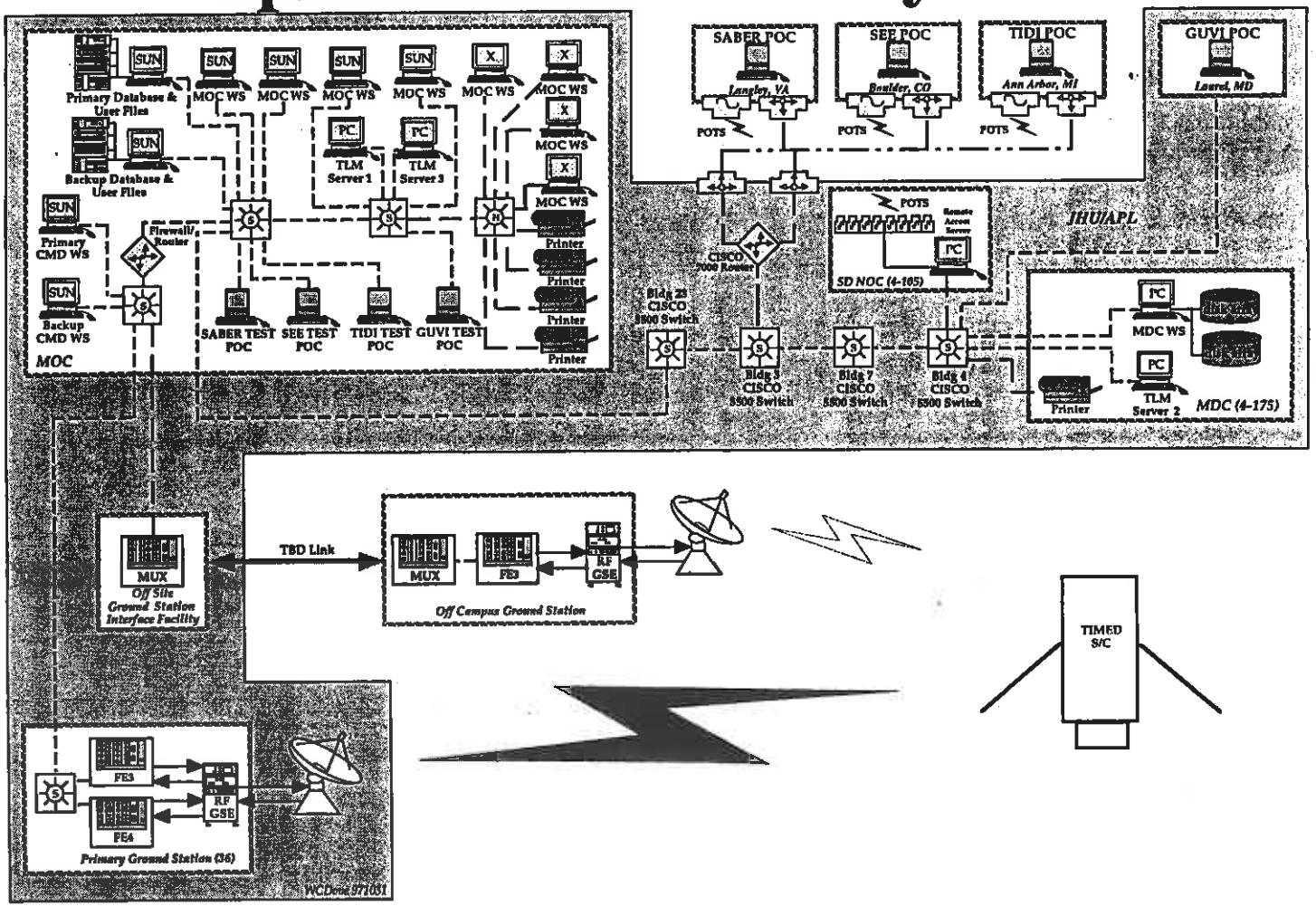
Operations Ground System



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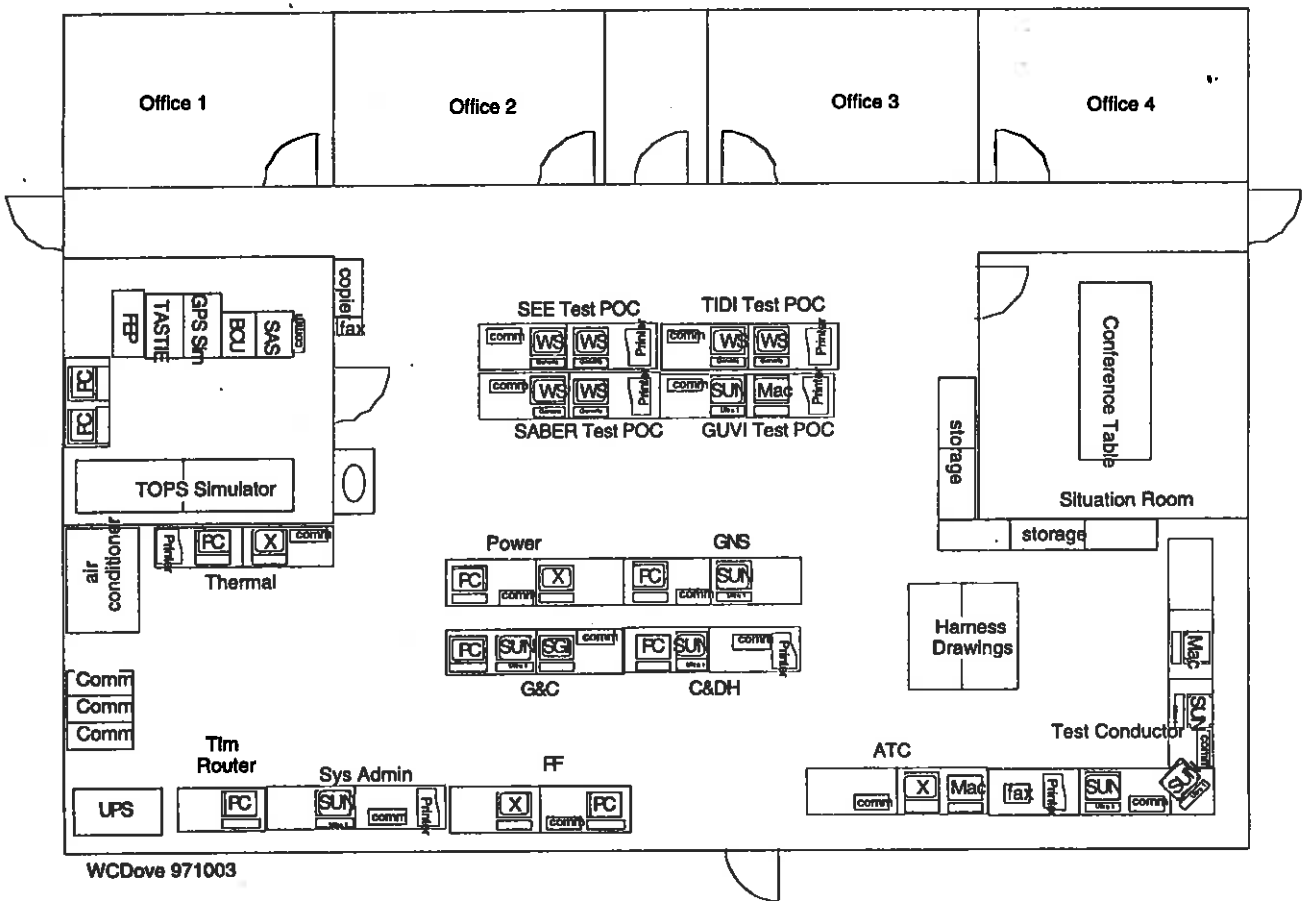
MOC Facility Layout (Tentative)



Ground Station Coverage

- **Primary Ground Station (APL)**
  - **Dedicated to TIMED**
  - **Recover all data modes (10Kbps - 4Mbps)**
  - **Two clusters (2-3 passes) spaced about 12 hours apart**
    - » **25-35 minutes of possible contact time per day**
- **Backup Ground Station (Alaska)**
  - **Scheduled on demand**
  - **Recover data up to 2Mbps (10Kbps - 2Mbps; possibly 4Mbps)**
  - **7-8 consecutive passes each day**
    - » **65-75 minutes of possible contact time per day**

Spacecraft Simulator

- **Operated by MOT, located in MOC**
- **Nearly full hardware/software simulation**
- **To be used for:**
  - **Command sequence (scripts) verification/validation**
  - **New software test and verification**
  - **Anomaly resolution**
  - **MOT training**

A Day in the Life of the Mission Operations Team

- **A candidate timeline [times referenced to start (AOS) of scheduled daily contact]**
  - **Assume primary contact scheduled to start at T-0 and backup contact scheduled at T+100 (to be used if needed)**

» T-135 min	120 min	Contact planning
» T-15 min	15 min	Pre-contact tests
» T-0 min	10 min	Contact
» T+10 min	20 min	Playback data retrieval
» T+30 min	30 min	Cursory telemetry view
» T+60 min	120 min	Performance assessment

  - **Total elapsed time: 5.5 hours**
  - **If problem discovered during cursory view, prepare contingency plan for backup contact**

Operations Planning

- **Science Working Group provides experiment schedule and priorities throughout the planning cycle**
  - **Science experiments are scheduled 1-2 months in advance and the schedule is refined as execution time is approached**
  - **Project Scientist is Mission Operation Team point of contact to Science Working Group**

Operations Planning (con't)

- **Three stage process:**
  - **–Monthly (1-2 months out)**
    - **»Identify periods of high value data collection**
    - **»Schedule long-range spacecraft maintenance events (yaw maneuvers, etc.)**
  - **–Weekly (1-2 weeks out)**
    - **»Schedule ground contacts (primary and backup)**
    - **»Update spacecraft operational schedule**
  - **–Daily (1 day out)**
    - **»Prepare ground antenna tracking elements**
    - **»Prepare spacecraft operation and maintenance commands**
    - **»Prepare data retrieval (SSR playback) commands**
    - **»Monitor and control instrument command queues**
    - **»Develop contact plan (script)**

Operations Control

- **Pre-contact readiness test (MOC and GS)**
- **Contact operations**
  - **Acquire spacecraft, monitor state of health**
  - **Initiate and monitor SSR playback**
  - **Uplink spacecraft maintenance commands**
  - **Release instrument command queues**
  - **Uplink contact termination commands**
  - **Recover SSR playback data from Ground Station**
  - **Release Ground Station control**
  - **Prepare 'as-run' contact plan**

Estimated Daily Command Volume

- **Normal Daily Operations (worst-case estimates)**
  - **Spacecraft bus: 2200 bytes per day (10 seconds uplink)**
    - » **IEM: 1000 bytes/day, G&C: 1000 bytes/day, power: 200 bytes/day**
  - **Instruments: 8000 bytes per day (40 seconds uplink)**
    - » **Each instrument (GUVI, SABER, SEE, TIDI): 2000 bytes/day**
  - **Total of 50 seconds per day is only about 10% of a typical contact period.**

Special and Contingency Commanding

- **Processor memory loads (complete replacement)**
  - **Instruments (no redundancy)**
    - » **GUVI, SEE can be loaded during one contact**
    - » **TIDI can be loaded during two contacts**
  - **Spacecraft bus (all are redundant)**
    - » **G&C AIU can be loaded during one contact**
    - » **GNS can be loaded during 4-5 contacts**
    - » **C&DH can be loaded during 2-3 contacts**
    - » **G&C FC can be loaded during 8-10 contacts**
- **Contingency commanding**
  - **Upload prepared contingency commanding scripts**

Processor Load and Dump Summary

Processor	Number	Subsystem	Memory Size (kilobytes)	Expected Load Size (maximum) (kilobytes)	Time to Load Expected Load Size (minutes)	Dump (packets per second)	Dump Duration to SSR (minutes)
Flight Computer (FC)	2	G&C	4000	1000	80	1	72
Attitude Interface Unit (AIU)	2	G&C	128	128	11	3	3
GPS Navigation System (GNS)	2	IEM/GNS	4000	500	40	1	36
Command and Data Handling System (C&DH)	2	IEM/C&DH	4000	256	20	1	18
GUVI	1	GUVI	64	64	6	2	2
SEE	1	SEE	80	80	7	2	3
TIDI	1	TIDI	192	192	18	2	6

NOTES:
1. Numbers are rounded off to next highest integer value
2. Upload duration assumes 80% of 2 kbps uplink bandwidth dedicated to actual memory contents

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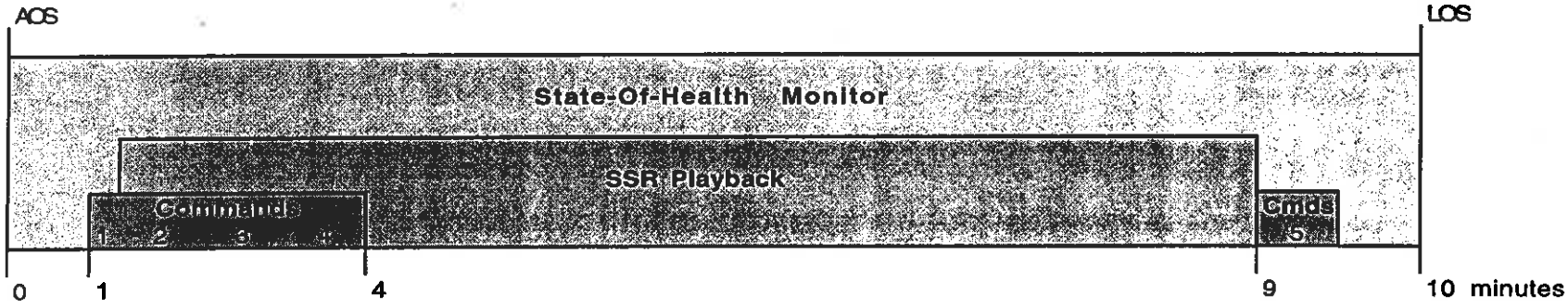
Typical Contact Timeline



Command Segment	Function	Estimated Duration
1	Initiate SSR playback (real-time commands)	30 seconds
2	Spacecraft bus maintenance (real-time commands)	40 seconds
3	Spacecraft bus stored commands	40 seconds
4	Instrument commands	60 seconds
5	Terminate contact (real-time commands)	10 seconds

Performance Assessment

- **Quick-look (performed during contact and immediately after and prior to backup contact)**
  - **Cursory look at spacecraft state-of-health**
  - **Identify any configuration discrepancies**
  - **Monitor instrument status**
  - **Check command and autonomy history buffers**
  - **Evaluate SSR data recovery (quantity and quality)**
- **Comprehensive**
  - **Process entire data set (since last assessment)**
  - **Plotting and trending**
  - **Prepare reports**
  - **Spacecraft bus diagnostic data processed and analyzed by engineering development teams (on demand only)**

SSR Management

- **Recording**
  - **Normal operations: Overwrite when full (current baseline concept)**
  - **High priority operations: Do not overwrite when full**
    - » **Preserve data for single day experiments and last day of multiple day operations (TBD prior to last day)**
- **Playback**
  - **Normal operations: Use daytime contacts only (minimum of one 10 minute contact required)**
  - **High priority operations: Use all available contacts**
    - » **Possible use of backup ground station as insurance**
  - **Consider using all available primary GS contacts routinely to recover multiple copies of SSR data**

SSR Playback Options

- **Baseline concept**
  - **Playback complete contents once per day**
  - **Identify missing pieces between contacts**
  - **Recover missing pieces during a backup contact**
- **Alternate concepts being considered**
  - **Playback contents repeatedly using all daytime contacts**
    - » **Estimate two complete playbacks**
  - **Playback contents repeatedly using all daytime contacts and one nighttime contact**
    - » **Estimate three complete playbacks**

SSR Playback Validation

- **Determine if all downlinked SSR data was received on the ground**
  - **MDC provides catalog of data it received and was determined to be suitable for keeping**
  - **MOC provides (via spacecraft telemetry) a record of playback data blocks that spacecraft downlinked**
  - **Together, these can be processed to determine which, if any, transmitted blocks were not properly received by the MDC. These blocks then may be retransmitted during a backup contact (provided these blocks have not been overwritten)**
- **Next (backup) contact must be used to recover any missing data, else it may be overwritten**

'Lights-out' Demonstration

- **Conduct contact operations without operators**
- **Script-driven contact plan**
  - **Autonomously monitor spacecraft state-of-health**
    - » **Alert MOT of any anomalous behavior**
  - **Playback SSR**
- **These are not required operations, are considered as a demonstration only.**
  - **Will start slow and build up**
  - **Will be routinely scheduled if successful**
  - **Will enhance likelihood of full data recovery from spacecraft**
- **Ground system is designed to support this**

Operations Phases

- **Pre-launch**
  - Mission Operations System development
  - Mission Operations Team training
  - Test the spacecraft as we intend to fly it
- **Launch and on-orbit evaluation**
  - Orbit characterization
  - Spacecraft bus checkout
  - Instruments checkout and calibration
- **Operational**
  - Long-term science data collection
  - Special operations (maneuvers, software updates, etc.)

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Mission Operations Team

- **Two teams, each staffed as follows:**
  - **Shift leader**
  - **Command Analyst**
  - **Telemetry Analyst**
  - **Ground system hardware/software support engineer**
- **Acquired early in program**
  - **During design phase (to learn how it works)**
  - **Participate in subsystem test phase**
  - **Comprise the bulk of spacecraft Integration and Test Team**
  - **Develop 'test-it-as-you-fly-it' procedures**
  - **Well-trained at time of spacecraft launch**

Organization and Staffing Plans

- **MOT Support of Integration and Test Team**
  - **MOT will be acquired and phased in during the spacecraft development and test phases and will support:**
    - » **Spacecraft bus subsystem testing**
    - » **Spacecraft bus integration and tests**
    - » **Spacecraft system operational tests**
  - **MOT will become a functional part of the subsystem test and spacecraft integration and test teams**
    - » **Command and Telemetry Dictionary development**
    - » **MOC display page development**
    - » **Spacecraft, MOC and ground station command and control script development**
    - » **Spacecraft mission simulations timeline and command script development**

Organization and Staffing Plans

- **Spacecraft Integration and Test Teams (3)**
  - **Test Conductor (*MOT will staff system tests*)**
    - » ***Focus on test procedure execution***
  - **Spacecraft Specialist (*MOT will staff*)**
    - » ***Focus on spacecraft performance***
  - **Ground System Engineer**
    - » ***Focus on GSE/MOC hardware and software***
  - **Ground Support System Engineer**
    - » ***Focus on operating test equipment***
- **MOC Development Team**
  - **Hardware/software engineers (*2 to become MOT*)**

Organization and Staffing Plans

- **Mission Operations Team staffing profile**

Position	Start	Function/Focus
– Spacecraft Specialist	1/97	Integrated Electronics Module
– Spacecraft Specialist	4/97	Guidance and Control subsystem
– Spacecraft Specialist	7/97	MOC operations
– Spacecraft Specialist	9/97	GNS subsystem
– Spacecraft Specialist	12/97	Spacecraft system testing
– Spacecraft Specialist	7/98	Spacecraft system testing

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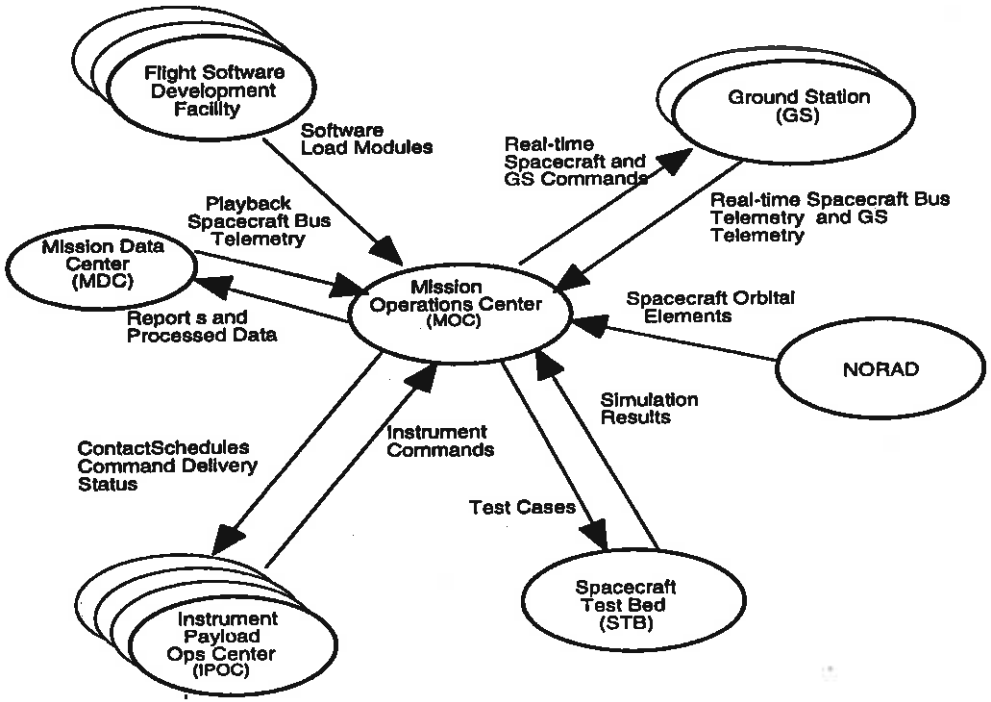
  - » Subsystem tests: 7/97 - 9/98
  - » Spacecraft integration and test: 9/98 - 6/99

» Spacecraft Specialists also act as Test Conductors during I&T

Mission Operations Center Interfaces



Documents

- **Concept of Operations (released March 1997)**
  - **A plan for spacecraft and ground system operations**
- **Operations Handbook**
  - **Operational procedures for spacecraft and ground system**
  - **Spacecraft operating rules and constraints**
- **Contingency Plans and Procedures**
  - **Detection of spacecraft and ground system anomalies and how to react to them**
- **Early On-orbit Operations Plan**
  - **The spacecraft on-orbit turn-on, checkout, evaluation and calibration plan**

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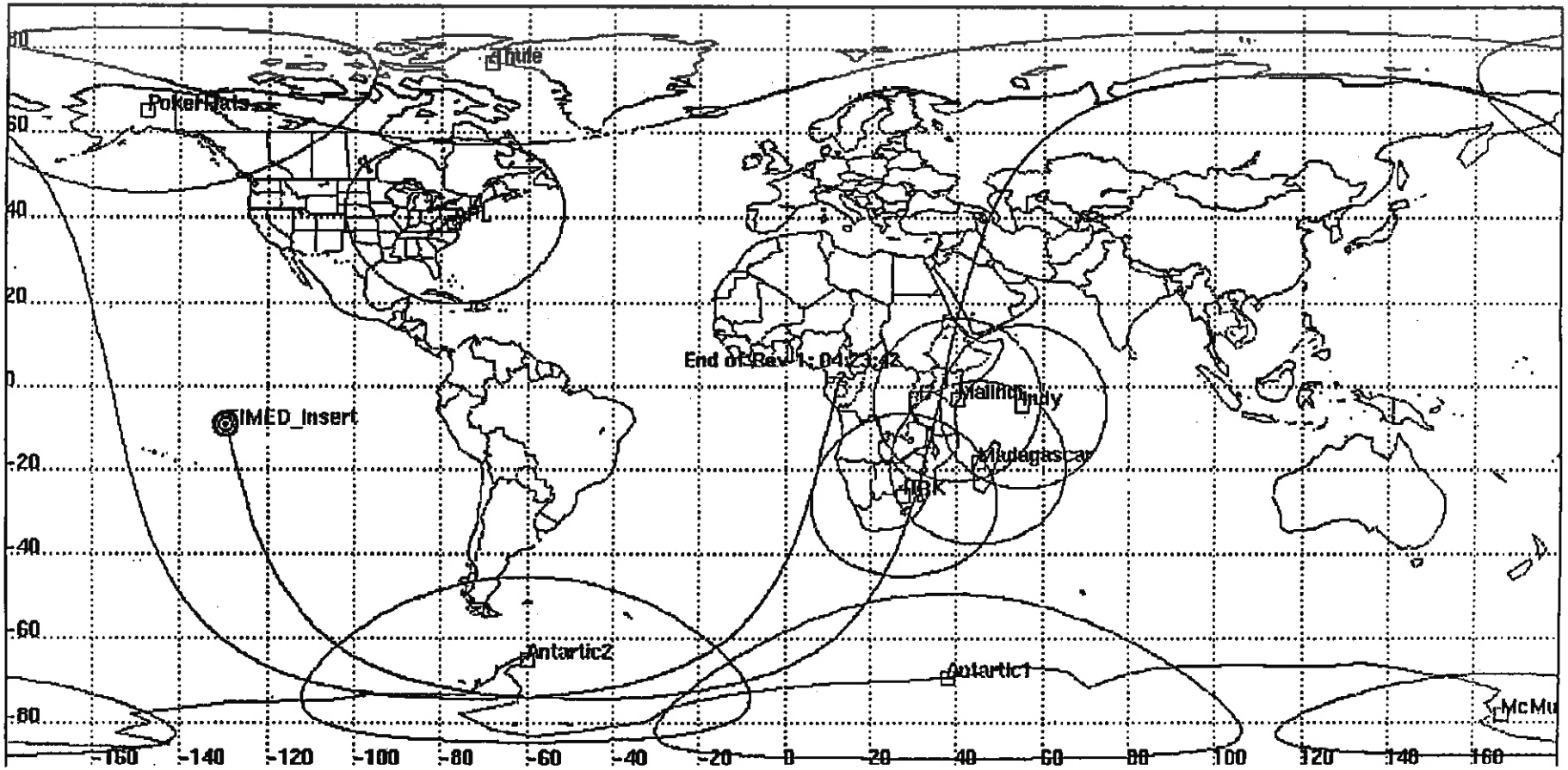
Orbit Insertion and Rev 1



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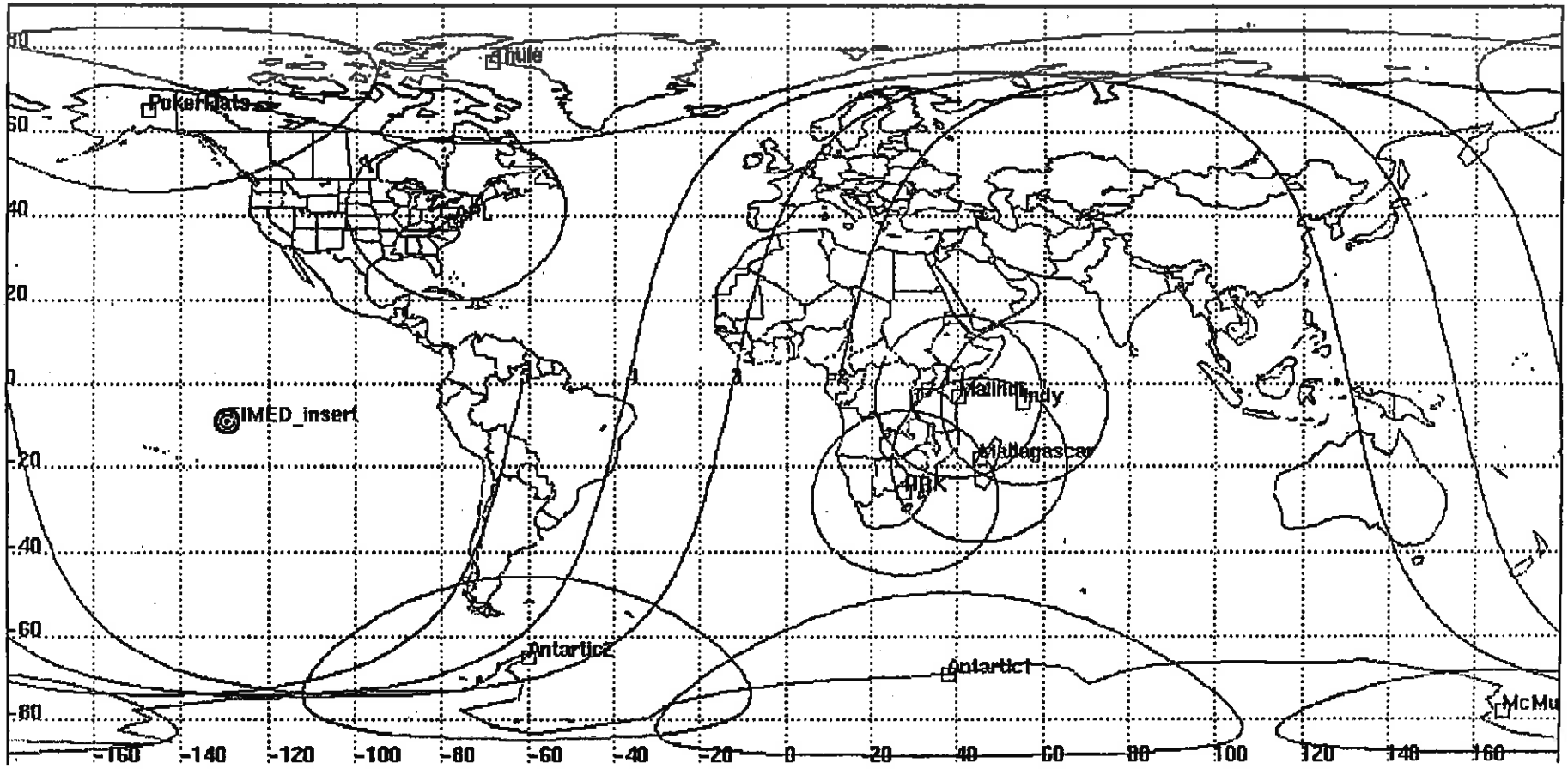
Revs 2-4



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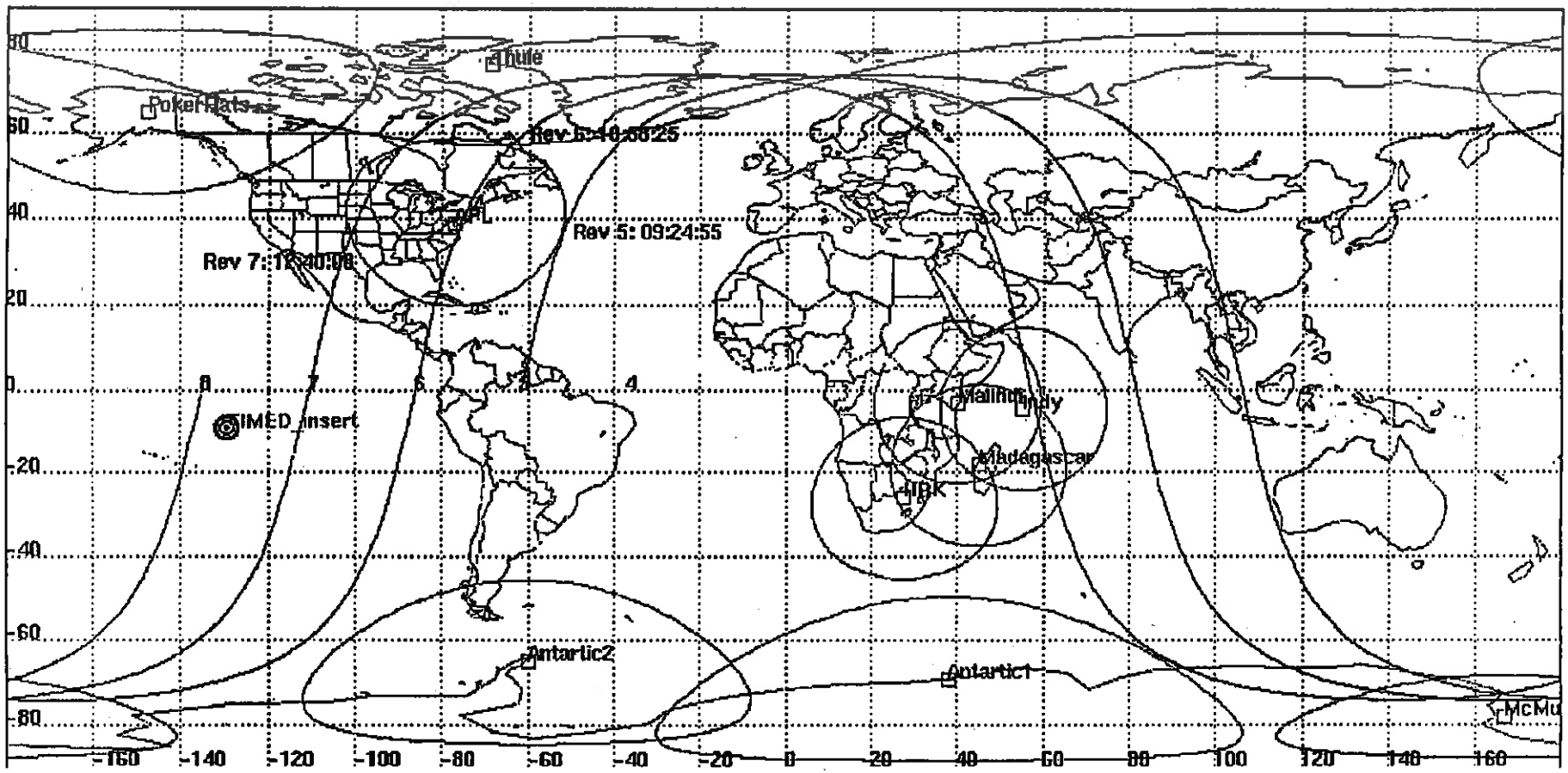
Revs 5-7 First APL Contacts



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Early Contacts - Revs 0-7

Orbit Rev	Time after separation (hh:mm:ss)	Duration (mm:ss)	Station
0	0:07:10	11:18	Antarctica 1
0	0:09:04	12:58	Antarctica 2
0	0:27:13	13:24	HBK
0	0:31:03	11:51	Madagascar
0	0:34:12	13:13	Malindi
0	0:37:05	8:14	Indy
1	1:09:13	6:46	Poker Flat
1	1:49:18	12:57	Antarctica 2
1	1:57:02	5:50	Antarctica 1
1	2:08:09	8:19	HBK
2	3:28:59	13:29	Antarctica 2
3	5:03:17	5:03	McMurdo
3	5:08:11	13:27	Antarctica 2
4	5:50:48	6:49	Thule
4	6:40:14	7:11	McMurdo
4	6:47:24	11:28	Antarctica 2
5	7:19:54	1:44	APL
5	7:26:00	10:25	Thule
5	8:18:19	7:56	McMurdo
5	8:28:06	4:19	Antarctica 2
6	8:53:25	10:59	APL
6	9:02:42	12:19	Thule
6	9:56:55	8:05	McMurdo
7	10:35:08	6:46	APL
7	10:40:30	13:12	Thule
7	11:08:22	13:19	Indy
7	11:08:51	9:40	Malindi
7	11:12:50	10:37	Madagascar
7	11:28:27	8:02	Antarctica 1
7	11:35:41	7:53	McMurdo

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Early Contacts - Revs 8-13

Orbit Rev	Time after separation (hh:mm:ss)	Duration (mm:ss)	Station
8	12:17:19	5:19	Poker Flat
8	12:19:00	13:30	Thule
8	12:45:58	12:54	Malindi
8	12:50:23	12:49	Madagascar
8	12:50:31	6:48	Indy
8	12:51:44	12:20	HBK
8	13:03:50	12:04	Antarctica 1
8	13:14:30	7:04	McMurdo
9	13:52:36	10:15	Poker Flat
9	13:57:50	13:32	Thule
9	14:30:49	12:00	HBK
9	14:41:28	13:28	Antarctica 1
9	14:53:40	13:37	McMurdo
10	15:30:56	11:07	Poker Flat
10	15:36:42	13:23	Thule
10	16:20:30	13:36	Antarctica 1
11	17:10:52	10:32	Poker Flat
11	17:15:25	12:47	Thule
11	17:26:43	5:33	APL
11	17:56:47	7:34	Antarctica 2
11	18:00:12	13:27	Antarctica 1
12	18:51:14	10:07	Poker Flat
12	18:54:02	11:22	Thule
12	19:03:45	11:01	APL
12	19:31:52	12:19	Antarctica 2
12	19:39:52	13:32	Antarctica 1
13	20:31:05	10:39	Poker Flat
13	20:32:42	8:36	Thule
13	20:45:07	4:47	APL
13	21:09:44	13:36	Antarctica 2
13	21:19:11	13:37	Antarctica 1
13	21:39:58	7:22	Indy