LANDSAT DATA CONTINUITY MISSION (LDCM) SAFE OPERATIONS ASCENT DESIGN

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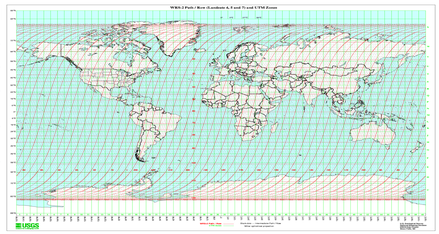
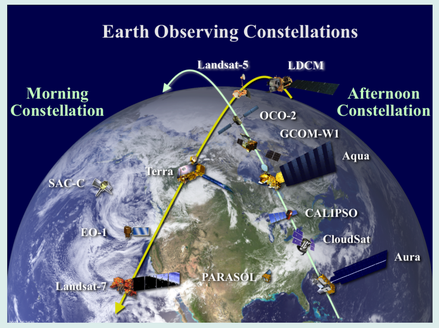
LDCM Mission Purpose

- Continue to observe and measure Earth's landscape as part of the Landsat 40+ year program (8th spacecraft)

Parameter	Value
Equatorial Altitude (km)	705 +/-1
Inclination (deg)	98.2 +/-0.15
Eccentricity	<=0.00125
Mean Local Time Descending Node (min)	10:00 am +/-15
Ground Trace Error WRS2 Grid	+/-5 km cross track at DN
Repeat Cycle (days) (WRS-2 World Reference System 2)	16 (233 orbits) LDCM will be phased to view the same ground scene that Landsat-7 saw 8 days earlier



- LDCM is a morning constellation spacecraft
  - Landsat-7, Landsat-5, Terra are all Sun synchronous at ~ 10:00 am MLT Descending Node
- The afternoon constellation "A-Train" operates at ~ 1:30 pm MLT Ascending Node
  - All are maintaining a frozen orbit at 705-km equatorial radius
  - Similar orbit geometry at different mean local time
  - Crossing at the northern and southern points
  - Very small radial separation at crossing points
  - Careful design of the on-orbit location to ensure along-track safety distance



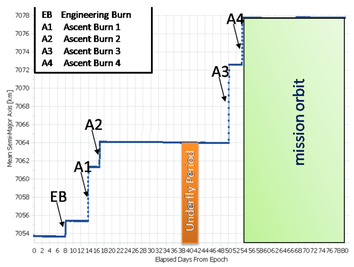
705-km "Neighborhood"

Nominal Ascent

LDCM will launch 25-km below the operational altitude

Launch Vehicle Provides a 10:11 am +/- 1 minute MLT at injection

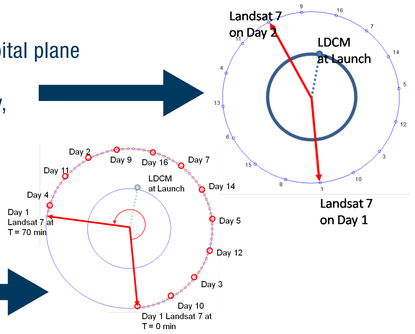
- Ascent Maneuver constraints
  - Begin ascent no earlier than 8 days after launch
  - Ascent maneuvers preferably phased 3 days apart for best operations tempo
  - Imaging tests with Landsat-7 NET days 38-42 of the mission. This orbital phase is termed the Landsat-7 "underfly"



- A1 & A2 Δv magnitudes were optimized to
  - Meet the Landsat-7 underfly constraint
  - Remain well below the 705-km constellation fleet envelope until mission orbit is achieved

The Landsat-7 and LDCM relative orbital plane geometries change significantly:

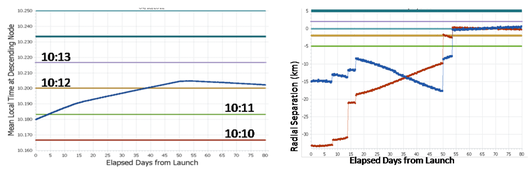
- For each daily launch opportunity, LDCM/Landsat-7 phasing moves 202.5° per day
- Over the course of a 70-minute launch window, LDCM/Landsat-7 phasing moves 3.7° per minute



Nominal Ascent Results

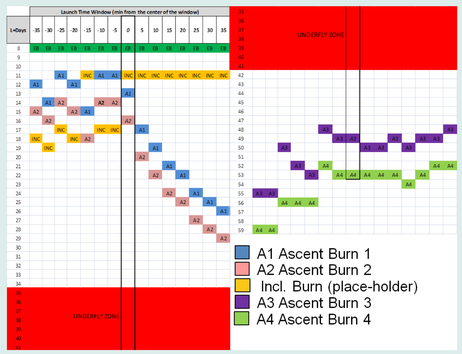
Burn ID	Burn Start Epoch (UTC)	Burn Duration (sec)	BurnDV (m/s)	Burn Fuel Used (m/s)	Days Since Lauch	Catch Rate (deg/day)	Synodic Period (days)
EB	Jan 23 2013 20:55:10.179	10	1.3	0.917	8	24.56	14.6
A1	Jan 29 2013 16:35:42.046	34.9	4.5	3.150	13.86	17.96	20
A2	Feb 01 2013 15:53:48.990	16.43	2.1	1.472	16.84	14.85	24
INC	Feb 04 2013 16:05:46.397	0	0	0	19.85	14.86	24
A3	Mar 06 2013 21:38:48.092	51.87	6.5	4.542	50.08	5.4	66
A4	Mar 10 2013 08:55:14.302	31.55	3.9	2.726	53.55	-0.33	n/a
	Totals →		18.3	12.807			

- Mean Local Time is within the required 10:10-10:15 during the ascent



Launch Time Variations

- A different ascent scenario was designed for every 5 min of launch time delay for a launch date of January 15, 2013
- The inclination maneuver is a placeholder if needed
- 5 minutes of launch delay is approximately 18.5° of phasing between LDCM and Landsat-7



Contingency Risk Matrix

LIKELIHOOD	1	2	3	4	5
5	3C				
4					
3			2F 3D 3A 2E		
2	1B 1C	1A	2A 2D 2B 3B 2C		
1		3G		3A 3F 3E	

CONSEQUENCE

LIKELIHOOD	CONSEQUENCE
1 Rare	1 Insignificant
2 Unlikely	2 Minor
3 Possible	3 Moderate
4 Likely	4 Major
5 Almost Certain	5 Extreme

Case #	Contingency Title	L	C
	Off-Nominal Performance		
1A	ΔV 10% magnitude and 10° errors (3σ)	2	2
1B	Orbit insertion SMA error (3σ)	2	1
1C	Orbit insertion inclination error (3σ)	2	1
	Contingencies based on 5-burn plan		
2A	Missed Ascent Burn 1 & Ascent Burn 2	3	2
2B	Missed Inclination Burn (Δi)	3	2
2C	Missed Ascent Burn 3 & Ascent Burn 4	3	2
2D	Partial burn	2	3
2E	Delay in ascent	3	3
2F	Delay in L7 underfly after first maneuvers	3	3
	Other Contingencies		
3A	Retrograde burns	3	3
3B	CA burns during ascent	2	2
3C	CA burns on orbit	5	1
3D	Speeding up to finish by day 90	3	3
3E	Autonomous/unplanned thrusting	1	4
3F	Direct to orbit without L7 underfly	1	4
3G	Loss of 1 thruster pair	1	2

Sample Contingency: Last Ascent Burn Missed

In case the last burn is missed, there exist two possible mitigations:

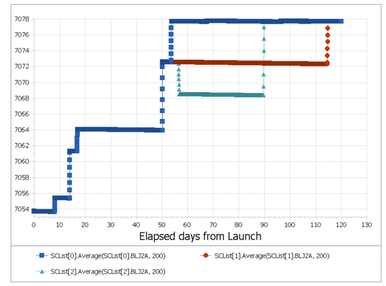
Option 1: wait a full synodic period and perform an insertion maneuver

Option 2: perform a retrograde maneuver to speed-up the once-around and perform an insertion maneuver

Option 1 is the preferred option if the 90 days maximum commissioning duration requirement is not violated

Option 2 is not as fuel efficient and requires two burns instead of one

However, both options are safe as far as interference with the "705-km neighborhood" members.



Scenario	Total DV (m/s)	Ascent Duration (Days)
Nominal	12.8	53
Option 1 (once around)	12.9	114
Option 2 (orbit lowering)	17	89

Sample Contingency: Underfly Period is Delayed

If delay notification happens prior to A1, A1-A4 can be replanned to meet the new underfly period

- If delay notification happens prior to A2, A2 timing and size can be adjusted to meet the new underfly constraint

Underfly Period (days)	Eng. Burn (L+days)	A1 (L+days)	A2 (L+days)	A3 (L+days)	A4 (L+days)
38-42	8	14	17	50	53
42-46	8	16	19	57	61
46-50	8	38	41	55	60
50-54	8	32	35	60	63
54-58	8	25	28	65	70
58-62	8	22	25	68	73

- If delay notification happens after A2
  - Option 1: wait a full synodic period (the new underfly period is delayed by 24 days) if the 90 days maximum period is not violated
  - Option 2: notified a week prior to the underfly that the underfly period needs to be delayed by one week (Ascent duration increases to 70 days)