A large graphic for the Delta II Gravity Probe-B Media Kit. At the top left, there are four grey squares and a cyan arrow pointing left with the word "SELECT" next to it. The main background is black with a blue grid pattern. The word "DELTA" is written in large, white, serif capital letters. Below it, "Gravity Probe-B" is written in large, yellow, serif capital letters. In the top right corner, a red digital timer shows "00:00:00". On the right side, there are four logos stacked vertically: a circular seal for "TESTING FINSTLIN'S UNIVERSITY", a red square logo for "Gravity Probe", the NASA logo, and a blue triangle with the Roman numeral "II". At the bottom right, the Boeing logo is visible. On the left side, there is a stylized image of a rocket launch with a bright orange and yellow flame and a cyan light trail.

DELTA

Gravity Probe-B

00:00:00

TESTING FINSTLIN'S UNIVERSITY

Gravity Probe

NASA

II

BOEING

Media Kit

This site requires a JavaScript-enabled browser and uses Flash for both animation and navigation. To get the full benefit of the [Boeing Web Site](#), you will need to download and install the latest version of the [Flash player](#), then return to view the [site](#).

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VIDEO



Delta II Rocks!

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Delta II Rolls!!

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Delta II-Eye-View!

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.rpm files require Realplayer plug-in installed for viewing



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PHOTO GALLERY



Previous Scientific missions



MER-A, 10 June, 2003

A Boeing Delta II rocket successfully delivered to space NASA's Mars Exploration Rover-A, also named *Spirit*, that launched at an instantaneous window of 1:58:47 p.m. EDT from Space Launch Complex 17A, Cape Canaveral Air Force Station, Fla. The rover landed on Mars in early January, 2004.



MER-B, 7 July, 2003

Opportunity, the second of two that will land on Mars, was launched by a Boeing Delta II launch vehicle from Launch Complex 17B, Cape Canaveral Air Force Station, Fla. Liftoff occurred at 1:58:47 p.m. EDT. Approximately 80 minutes after liftoff, *Opportunity*, or Mars Explorer (MER)-B, was deployed in its trajectory and landed on Mars.

Gravity Probe-B



Gravity Probe B in Cleanroom

The Gravity Probe B spacecraft is pictured in NASA's payload processing facility at Vandenberg Air Force Base, Calif., after completion of processing before going to the launch pad. A Delta II launch vehicle will deploy the satellite to a circular-polar orbit in April 2004 from Vandenberg. The mission will test two aspects of Einstein's general theory of relativity to determine if space time is distorted by Earth's presence in space as well as its rotational force.



Second Stage Mate

The second stage of the Delta II launch vehicle for NASA's Gravity Probe B mission was mated to the mobile service structure at Launch Complex 2W, Vandenberg Air Force Base, Calif. A Delta II will launch in April 2004 on a mission to test aspects of Einstein's general theory of relativity to determine if space time is distorted by Earth's presence in space.



Launch Vehicle Logos

The Gravity Probe B mission logos shown on the first stage booster of the Delta II rocket that will fly to space in April 2004 from Vandenberg Air Force Base, Calif. Included are logos from the Boeing Delta team, the Gravity Probe B mission team and NASA. Gravity Probe B will validate the frame-dragging effect and the geodetic effect, two predictions made from Einstein's general theory of relativity, that Earth's presence and rotation in space warps space time.



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Gravity Probe B in Cleanroom



The Gravity Probe B spacecraft is pictured in NASA's payload processing

facility at Vandenberg Air Force Base, Calif., after completion of processing before going to the launch pad. A Delta II launch vehicle will deploy the satellite to a circular-polar orbit in April 2004 from Vandenberg. The mission will test two aspects of Einstein's general theory of relativity to determine if space time is distorted by Earth's presence in space as well as its rotational force.

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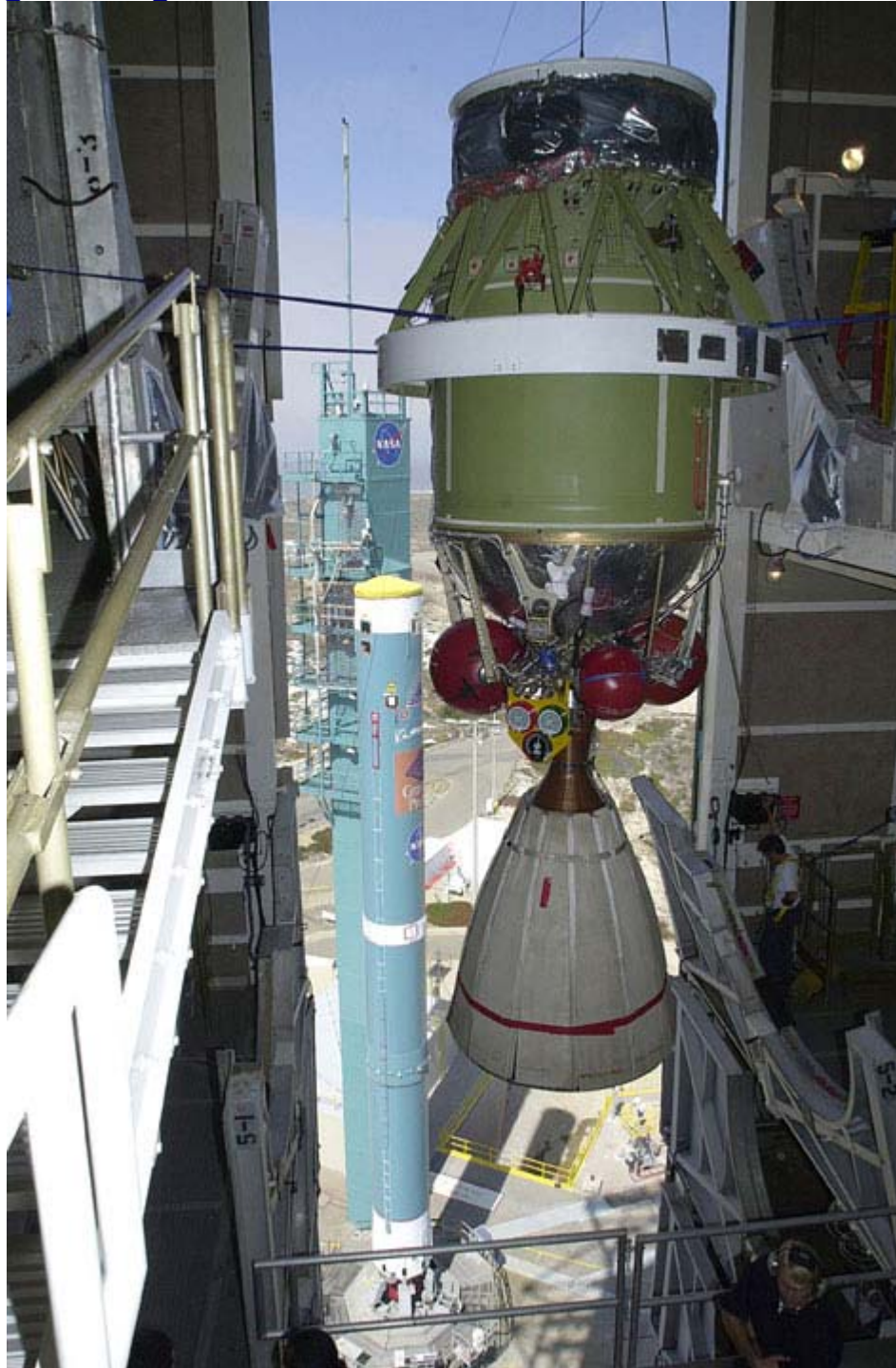
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PHOTO GALLERY



Second Stage Mating



The second stage of the Delta II launch vehicle for NASA's Gravity Probe B mission is

raised by the mobile service tower at Space Launch Complex 2W, Vandenberg Air Force Base, Calif. A Delta II will launch the satellite in April 2004 on a mission to validate two aspects of Einstein's general theory of relativity to determine if space time is distorted by Earth's presence and rotation in space.

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Launch Vehicle Logos



The Gravity Probe B mission logos shown on the first stage booster of the

Delta II rocket that will fly to space in April 2004 from Vandenberg Air Force Base, Calif. Included are logos from the Boeing Delta team, the Gravity Probe B mission team and NASA. Gravity Probe B will validate the frame-dragging effect and the geodetic effect, two predictions made from Einstein's general theory of relativity, that Earth's presence and rotation in space warps space time.

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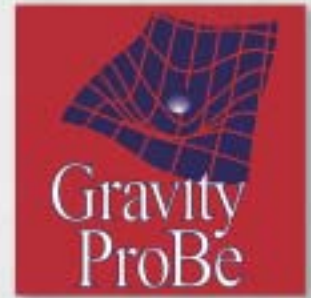
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Gravity Probe-B

DELTA  II

Delta Launch Vehicle Programs



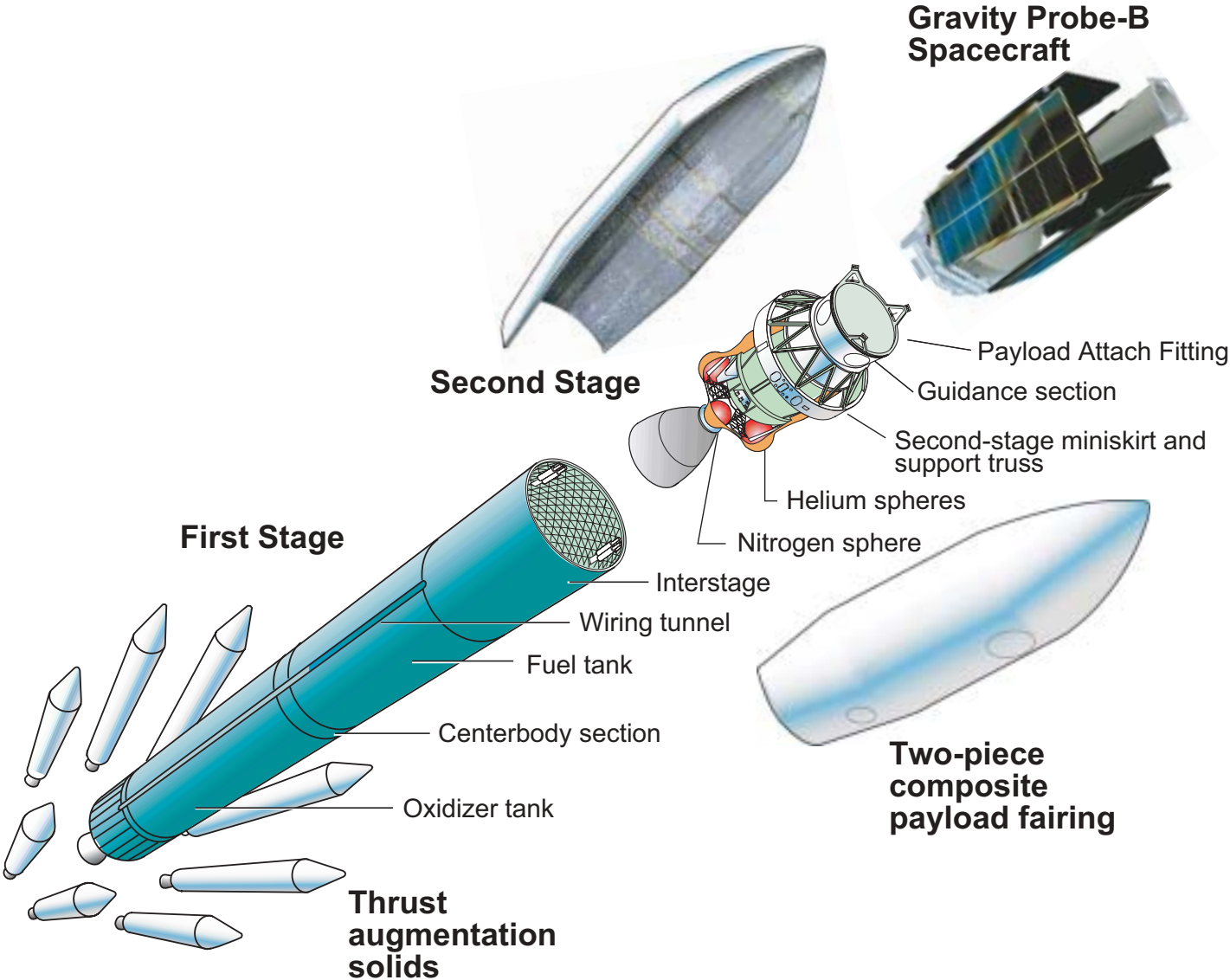
Gravity Probe-B Mission Objectives

- The Gravity Probe-B mission tests the predictions of Albert Einstein's General Theory of Relativity
 - Gravity is interpreted not as a force, but as a field distorting time and space
- Gravity Probe-B measures two phenomena predicted by the Theory of Relativity in an effort to prove or disprove Einstein's theory
 - The Geodetic effect
 - The frame-dragging effect

Gravity Probe-B Science Instruments

- The geodetic and frame-dragging effects will be tested by measuring tiny changes in the direction of spin of four ultra precise gyroscopes
 - The gyroscopes are capable of measuring change in direction to 0.1 milliarc-second (the width of a human hair as seen from 100 miles)
- Movement of the gyroscope spin axes relative to an inertial frame is measured by observing a guide star through a telescope and maintaining the spacecraft attitude with a helium-based gas thruster system

Delta II 7920-10 Launch Vehicle



Gravity Probe-B Mission Requirements

• Launch vehicle/payload attach fitting	7920-10/6019 PAF
• Launch site	VAFB SLC-2W
• Launch date	April 17, 2004
• Launch opportunity	One per day
• Launch window	One second
• Spacecraft mass (kg/lb)	3186.8/7025.69
• Orbit requirements	
– Semi-major Axis (km/nmi)	7027.4/3794.5
– Eccentricity	0.00140
• Apogee altitude (km/nmi)	659.1/355.9
• Perigee altitude (km/nmi)	639.5/345.3
– Inclination (deg)	90.007
– Argument of Perigee (deg)	71.3
• Probability of Command Shutdown (PCS)	99.73%

Gravity Probe-B Flight Mode Description

- Launched from Vandenberg Air Force Base (VAFB) SLC-2W
- Flight azimuth of 196 degrees
- 6/3 solid motor firing sequence
- Separation of ground-ignited GEMs at 86 and 87 sec to assure clearance of coastal oil platforms
- Double dog-leg maneuver performed to attain required orbital inclination
- Payload fairing jettisoned when free molecular heating rate $\leq 0.1\text{BTU/ft}^2\text{-sec}$ (1135 Watts/m^2)
- Command Receiver Decoders (CRDs) turned off at 434 sec
- Second stage first burn places vehicle in a 90 x 352 nmi (167 x 652 km) orbit with an inclination of 90.014 deg
 - Mobile Telemetry (MT) required for coverage of last portion of second-stage burn

Gravity Probe-B

Sequence of Events – Boost-to-Orbit

Event	Time (hr:min:sec)
Liftoff	00:00:00.0
Mach 1	00:00:33.1
Maximum Dynamic Pressure	00:00:47.8
Solid Motor Burnout (6)	00:01:04.0
Solid Motor Ignition (3)	00:01:05.5
Solid Motor Separation (3)	00:01:26.0
Solid Motor Separation (3)	00:01:27.0
Begin Double Dog-leg Maneuver	00:01:30.0
Solid Motor Burnout (3)	00:02:09.7
Solid Motor Separation (3)	00:02:11.5
End Double Dog-leg Maneuver	00:02:30.0
Main Engine Cutoff (MECO)	00:04:23.5
Stage I-II Separation	00:04:31.5
Stage II Ignition	00:04:37.0
Jettison Fairing	00:04:41.0
CRD Turnoff	00:07:14.0
First Cutoff – Stage II (SECO-1)	00:11:15.6

Gravity Probe-B Orbit Trace – Boost-to-Orbit

(ESTAR Min. for T/M Sites = 2.00 deg)



VTS = Vandenberg AFB
P-3 = NP-3D Aircraft

Gravity Probe-B Flight Mode Description – Coast and Restart

- Following SECO-1, vehicle reoriented to desired coast attitude
- At end of reorientation maneuver, coast roll rate of 1 deg per sec initiated
 - Sun angle to vehicle centerline of approximately 90 deg during coast roll
- At end of roll maneuver, vehicle reoriented to second-stage restart burn attitude
- Second-stage restart occurs at approximately 3698 sec over the Malindi, Kenya, tracking station
 - Restart burn duration is 16.2 sec
 - At end of second-stage restart burn (SECO-2), vehicle is in an orbit of 344.1 x 356.2 nmi (637.3 x 659.7 km) with an inclination of 90.007 deg

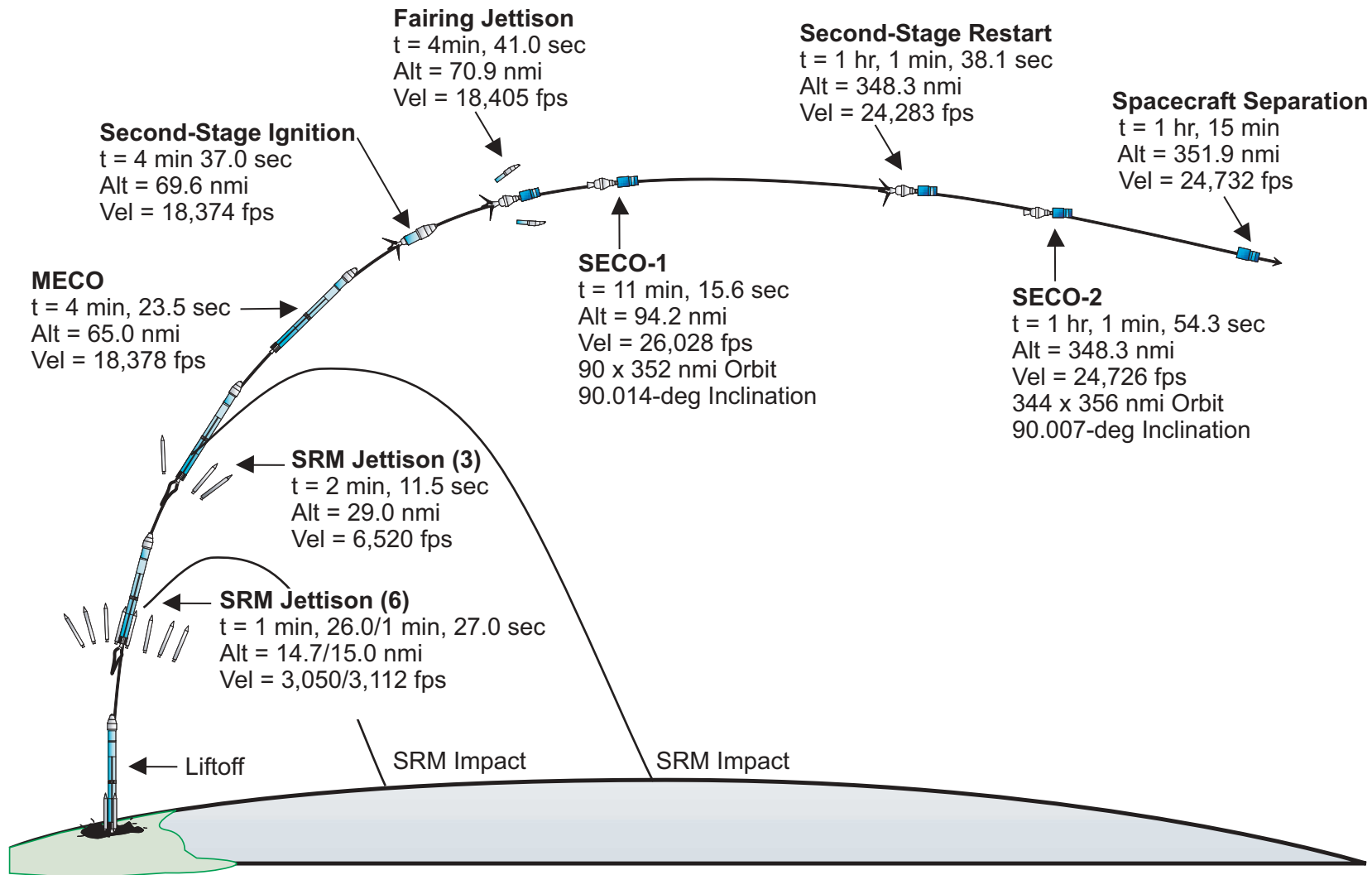
Gravity Probe-B Flight Mode Description – Spacecraft Separation

- Following second-stage restart burn, vehicle reoriented to the desired attitude for GP-B spacecraft separation
- Spacecraft solar panel deployment initiated at 4010 sec
- Launch vehicle initiates roll rate of 0.1 rpm required by spacecraft at 4450 sec
- Spacecraft separation occurs at 4500 sec over the Kiruna, Sweden, tracking station
 - GP-B uses a 6019 payload attach fitting (PAF) with a secondary latch system
 - PAF separation bolts fired at 4470 sec and secondary latches are released at 4500 sec separating the spacecraft

Gravity Probe-B Sequence of Events – Coast Through Spacecraft Separation

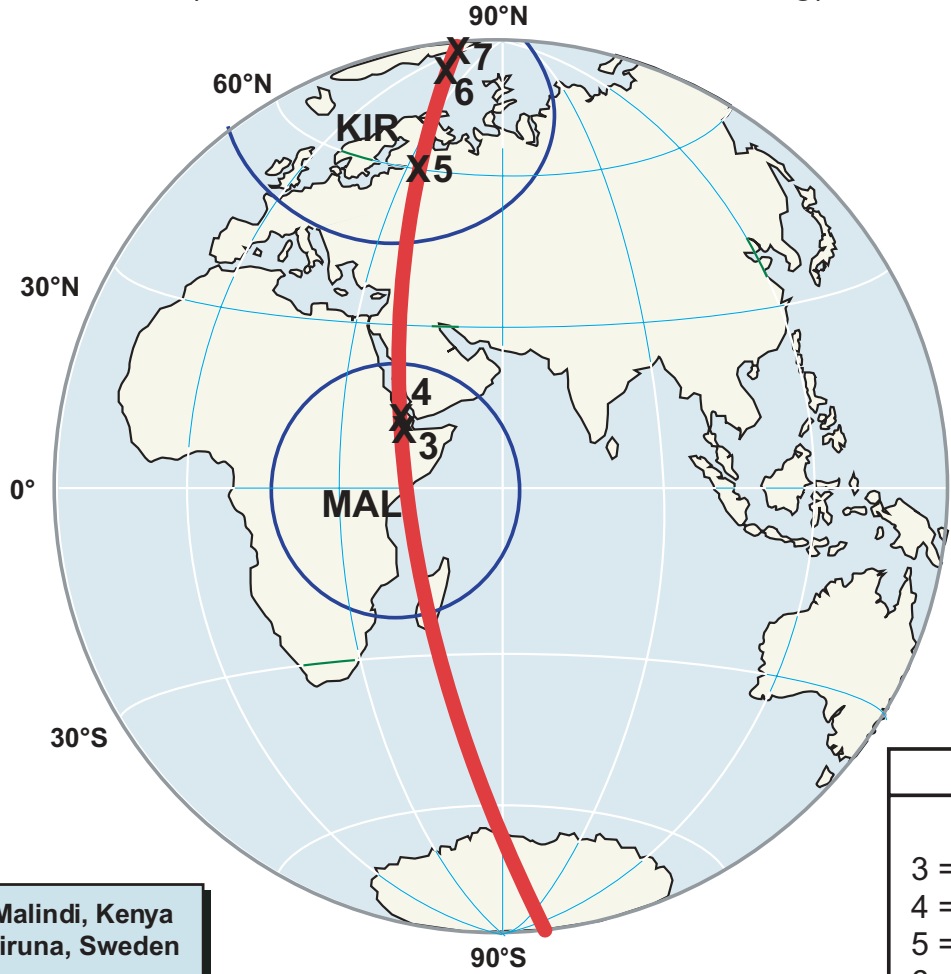
Event	Time (hr:min:sec)
First Cutoff – Stage II (SECO-1)	00:11:15.6
Begin Maneuver to Coast Attitude	00:13:10.0
End Maneuver to Coast Attitude	00:18:50.0
Begin Coast Roll Maneuver	00:19:00.0
End Coast Roll Maneuver	00:58:10.0
Begin Maneuver to Restart Attitude	00:58:20.0
End Maneuver to Restart Attitude	00:59:40.0
Stage II Restart Ignition	01:01:38.1
Second Cutoff – Stage II (SECO-2)	01:01:54.3
Begin Maneuver to Separation Attitude	01:02:30.0
End Maneuver to Separation Attitude	01:06:30.0
Begin Solar Panel Deployment	01:06:50.0
End Solar Panel Deployment	01:10:00.0
Begin Spacecraft Separation Roll Rate	01:14:10.0
Fire Explosive Separation Bolts	01:14:30.0
Spacecraft Separation	01:15:00.0

Flight Profile



Gravity Probe-B Orbit Trace – Coast and Restart

(ESTAR Min. for T/M Sites = 2.00 deg)



MAL = Malindi, Kenya
KIR = Kiruna, Sweden

Legend	
	Time (h/m/s)
3 = Restart Ign 1	(01:01:38.1)
4 = SECO-2	(01:01:54.3)
5 = GP-B Separation	(01:15:00.0)
6 = Begin Cold Gas Evasive	(01:20:50.0)
7 = End Cold Gas Evasive	(01:21:20.0)

Gravity Probe-B Flight Mode Description – Post-Separation

- Following spacecraft separation, second-stage retro initiated to move stage away from the spacecraft
- After second-stage retro, vehicle is reoriented to perform a cold gas evasive maneuver
- Following cold gas evasive maneuver, vehicle reoriented to attitude for second-stage evasive burn
- Second-stage evasive burn occurs over the Poker Flats, Alaska, tracking station and moves stage farther away from GP-B
 - Second-stage evasive burn attitude designed to ensure worst case spacecraft contamination level meets requirement of <10 Angstroms
- Following second-stage evasive burn, vehicle is reoriented and a depletion burn is performed to move the stage from the GP-B orbit plane

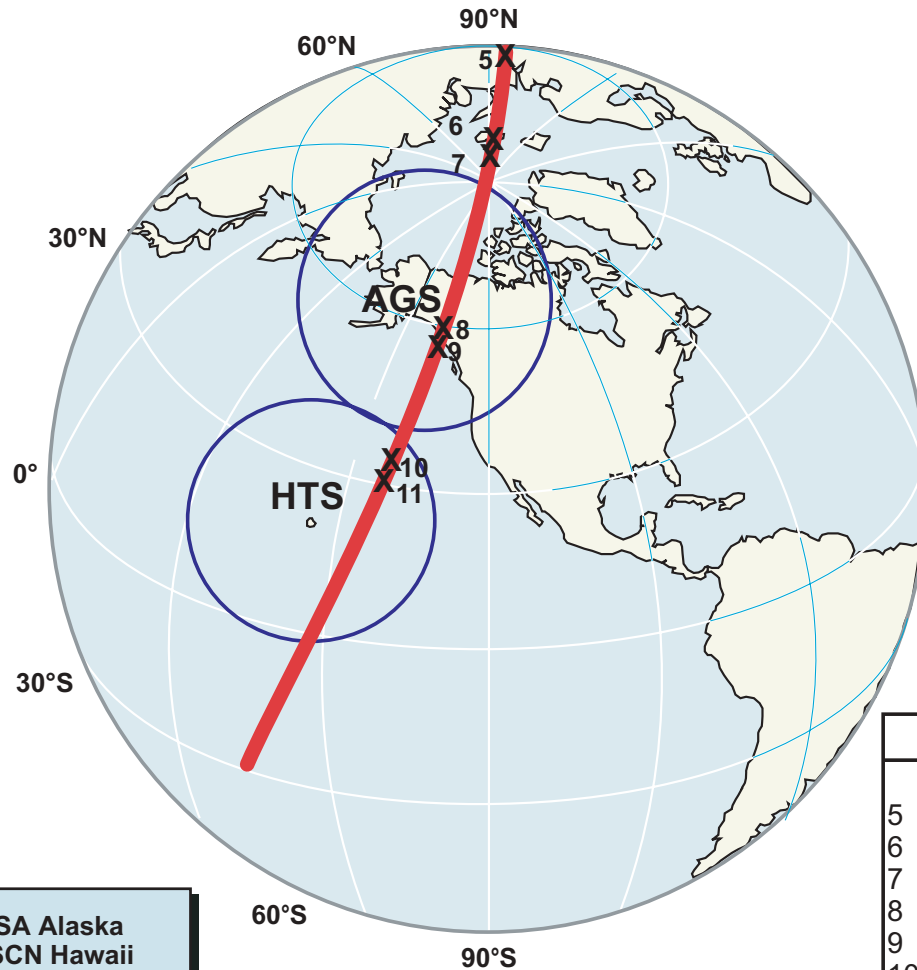
Gravity Probe-B

Sequence of Events – Post-Separation

Event	Time (hr:min:sec)
Spacecraft Separation	01:15:00.0
Begin Stage II Retro	01:15:00.5
End Stage II Retro	01:15:42.0
End Spacecraft Separation Roll Rate	01:15:50.0
Begin Maneuver to Cold Gas Evasive Attitude	01:16:00.0
End Maneuver to Cold Gas Evasive Attitude	01:20:40.0
Begin Cold Gas Evasive Maneuver	01:20:50.0
End Cold Gas Evasive Maneuver	01:21:20.0
Begin Maneuver to Evasive Burn Attitude	01:21:30.0
End Maneuver to Evasive Burn Attitude	01:29:40.0
Stage II Restart Ignition (Evasive Burn)	01:31:40.0
Third Cutoff – Stage II (SECO-3)	01:31:45.0
Begin Maneuver to Depletion Burn Attitude	01:32:00.0
End Maneuver to Depletion Burn Attitude	01:36:20.0
Stage II Restart Ignition (Depletion Burn)	01:38:20.0
Stage II Nominal Depletion Cutoff	01:39:05.1

Gravity Probe-B Orbit Trace – Post-Separation

(ESTAR Min. for T/M Sites = 2.00 deg)



AGS = NASA Alaska
HTS = AFSCN Hawaii

Legend	
	Time (h/m/s)
5 = GP-B Separation	(01:15:00.0)
6 = Begin cold gas evasive	(01:20:50.0)
7 = End cold gas evasive	(01:21:20.0)
8 = Restart ignition 2	(01:31:40.0)
9 = SECO-3	(01:31:45.0)
10 = Restart ignition 3	(01:38:20.0)
11 = Depletion cutoff	(01:39:05.1)

Integrated Defense Systems
P. O. Box 516
St. Louis, MO 63166
www.boeing.com

Boeing Delta II Gravity Probe B Mission

Mission:	Gravity Probe B
Date:	April 19, 2004
Time:	10:01:20 a.m. PDT (one-second window)
Launch Site:	Space Launch Complex 2W Vandenberg Air Force Base, Calif.
Launch Vehicle:	Boeing Delta II 7920-10
Customer:	NASA
Spacecraft Maker:	NASA Marshall Space Flight Center Stanford University Lockheed Martin Space Systems
Overview:	<p>Gravity Probe B will test two predictions of Albert Einstein's general theory of relativity called the Geodetic effect — the amount by which the Earth warps local space time in which it resides; and the frame-dragging effect — the amount by which the Earth drags local space time with it as it rotates.</p> <p>The spacecraft will send back data on changes in the spin axis direction of four onboard, ultra-precise gyroscopes in relation to the spacecraft's guide star, IM Pegasi, that will enable scientists to determine if space and time are distorted by the presence of massive objects such as the Earth.</p>

###

Contact:
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Boeing Launch Hotline: (714) 896-4770
Boeing Delta Web site: www.boeing.com/delta



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