



Wild 2 Encounter Expectations



Wild 2 Encounter

Expectations

presented to

NASA HQ

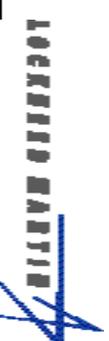
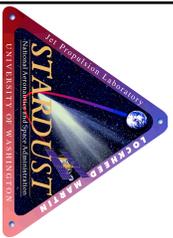
by the

The STARDUST Flight Team

01:00 - 03:00 pm

Wednesday 08 October 2003

8 Oct 2003 Brownlee / Duxbury / Chevront



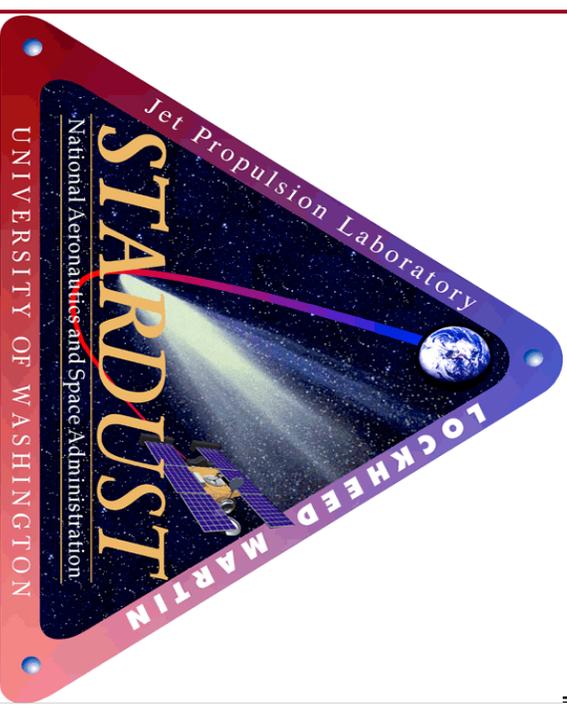


Stardust Overview



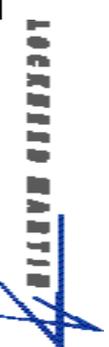
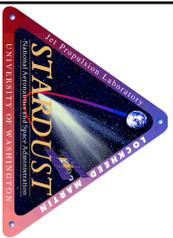
Salient Features

- **4TH NASA DISCOVERY PROJECT**
 - **PI-LED: PROF. DON BROWNLEE, UNIVERSITY OF WASHINGTON**
 - **LMA/DENVER INDUSTRIAL PARTNER**
 - **OVERSIGHT BOARD: PI, NASA DISCOVERY OFFICE, JPL DIRECTOR FOR, LMA VICE PRESIDENT**
- **COMET SAMPLE RETURN**
- **LAUNCHED JUST AFTER MS'98 (MCO/MPL) IN FEB 1999**
- **EARTH GRAVITY ASSIST TO REACH COMET WILD 2**
- **SOLAR POWERED OUT TO 2.7 AU**
- **ANNEFRANK FLYBY**
- **MOSTLY IN CRUISE MODE WITH ONE 4 HR DSN PASS/WEEK**
- **ENTRY CAPSULE AND PARACHUTES TO SOFT LAND IN THE UTAH TEST AND TRAINING RANGE**



Science

- **RETURN COMET AND INTERSTELLAR DUST PARTICLES USING JPL AROGEL/LMA SAMPLE RETURN CAPSULE**
- **COMET WILD 2 AND LUNAR IMAGES FROM JPL CAMERA**
- **IN-SITU MASS SPECTRA OF COMETARY AND INTERSTELLAR DUST FROM GERMAN MPI CIDA**
- **WILD 2 IN-SITU DUST SIZE AND SPATIAL DISTRIBUTION OBSERVATIONS FROM U of CHI DFMI**
- **INTEGRATED DUST AND NUCLEUS MASS ESTIMATE FROM JPL RADIO SCIENCE**
- **WILD 2 DUST PARTICLE SIZE AND SPATIAL DISTRIBUTION FROM LMA ATTITUDE RESPONSE TO PARTICLE HITS**

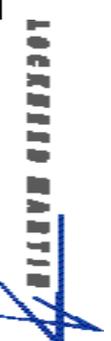
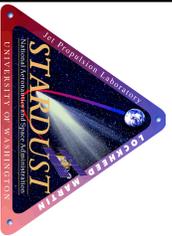




Meeting Objectives



- Reiterate that STARDUST is Performing Exceptionally Well
 - Schedule, Funding, S/C Resources
- Describe Knowledge Gained Since Launch
- Describe Effects of Current Comet Ephemeris and Dust Models on Flyby Distance
- Discuss Expected Spacecraft / Instrument Performance w/ Anticipated Science Return and Associated Risk During Wild 2 Flyby
- Propose Minor Changes to Mission Success Criteria
 - Reflects Updates to / Effects of Comet Models
 - Driven by Expected Results
 - Provides Excellent Science within Low Level of Risk





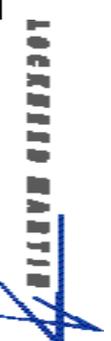
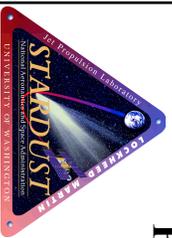
Punch Line



RECOMMEND TO INCREASE FLYBY DISTANCE FROM 150 KM TO 300 KM
(WITHIN PRE-LAUNCH RANGE OF ACCEPTABLE DISTANCES)

	FLYBY DISTANCE		
SCIENCE / RISK	150 KM	300 KM	≥600 KM
PRIMARY SCIENCE	YES	ACCEPTABLE	NO
SECONDARY SCIENCE	YES	ACCEPTABLE	NO
S/C RISK	NO <2 (94.8%)	ACCEPTABLE 2☐ (97.4%)	YES 3☐ (98.7%)

SPACECRAFT RISK < 2☐
COLLECTED PARTICLES CUT BY HALF BUT FULL PARTICLE SCIENCE STILL
POSSIBLE FROM IMPROVED EARTH-BASED PARTICLE INSTRUMENTS

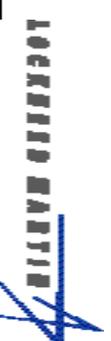
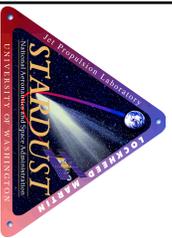




Knowledge Gained Since Launch



- **Camera Filter Wheel Stuck in Nav Cam (Broadband) Filter after Earth Flyby after Earth Flyby and Accumulates Contamination Near 1 AU (Reported to NASA HQ w/ Accompanying New Releases and Included in NASA Lessons Learned Archive)**
 - **No Color Images Possible**
 - **Effects of Contamination Reduced Significantly Using Heating**
 - **NASA Group Award for Effort**
 - **Images to be Taken in 2 Weeks to Assess Camera performance**
- **Wild 2 Ephemeris Uncertainty Increased the Time of Flight Uncertainty from 30 seconds to 180 seconds**
 - **Encounter Sequence Designed for 240 seconds (1,500 km)**
 - **New Sequence to Span 500 seconds (3,000 km)**
 - **Cannot Keep 65 Images Within 2,000 km (Objective)**
 - **Peer Reviewed (NAG) w/ Division and Section - Validated Model**

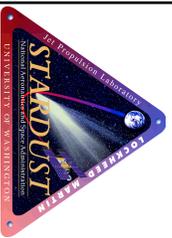




Knowledge Gained Since Launch



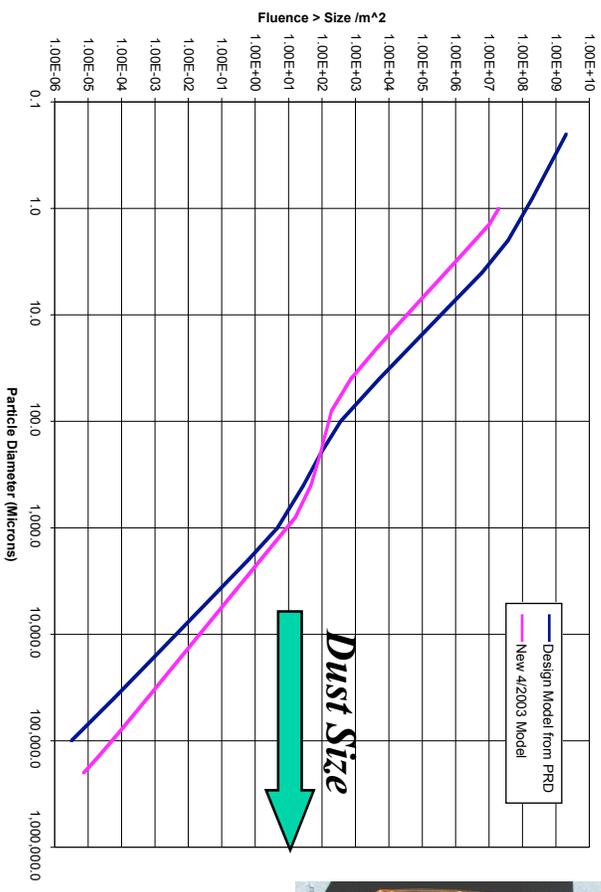
- During the last 2 years, Updates to the Wild 2 Dust Model Have Lowered the Expected Amount of Collectable Particles by 1 Order of Magnitude and Increased the Expected Amount of Larger Particles (S/C Threat) by 1 Order of Magnitude
 - Much more Independent Cometary Dust and Trail Analyses by International Researchers and Other Projects
 - More Modern Visual and IR Observations
 - Previous Models Gave Acceptable Flyby Distance Between 75 - 400 km
 - International Peer Review “Validated” Model
 - Now No Flyby Distance Meets Particle Collection and Risk Requirements
- DS1 Imaging of Comet Borrelly Stressed Importance of High Resolution Imaging for Dust Particle Context, Locations of Jets and Surface Studies
- Improvements to Earth-based Particle Instruments Allow Science Expected from 15 μ m Particles to be Obtained from 10 μ m Particles





Wild 2 Encounter Expectations

New / Related Information

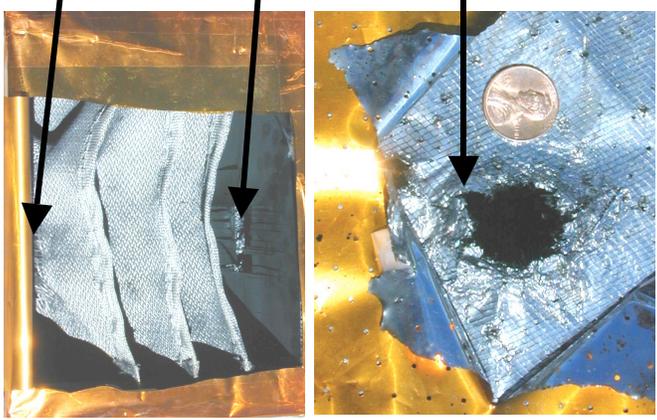


1 cm

2 cm

5 cm

11 cm



Borrelly Imaging Showing Surface Detail

NEAR1-1
47 meters

MID5-3
61 meters

MID4-1
91 meters

MID2-2
114 meters

MID2-1
122 meters

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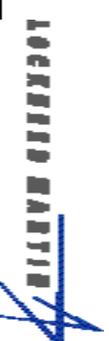
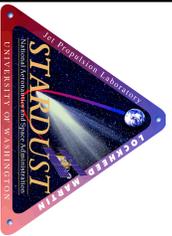


Wild 2 Science Requirements



- Particle Collection - Primary Science
 - # Particles $N \gg 100$ → ($N = 500$)
 - Needed to Obtain Complete Sample of Diverse Particle Environment
 - Needed to Perform Meaningful Statistical Analyses and Classifications of Broad Range of Particles
 - Imaging - Secondary Science
 - Image Resolution (not Pixel Scale) Must be DS1 Level at Borrelly or Better (65 m/pixel)
 - Needed to Resolve Source of Jet(s) for Context
 - Needed to Characterize Nucleus Surface for a Kuiper Belt Comet
 - Wild 2 Images Expected to be Smeared a few Pixels
- ↓

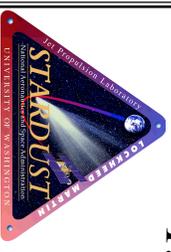
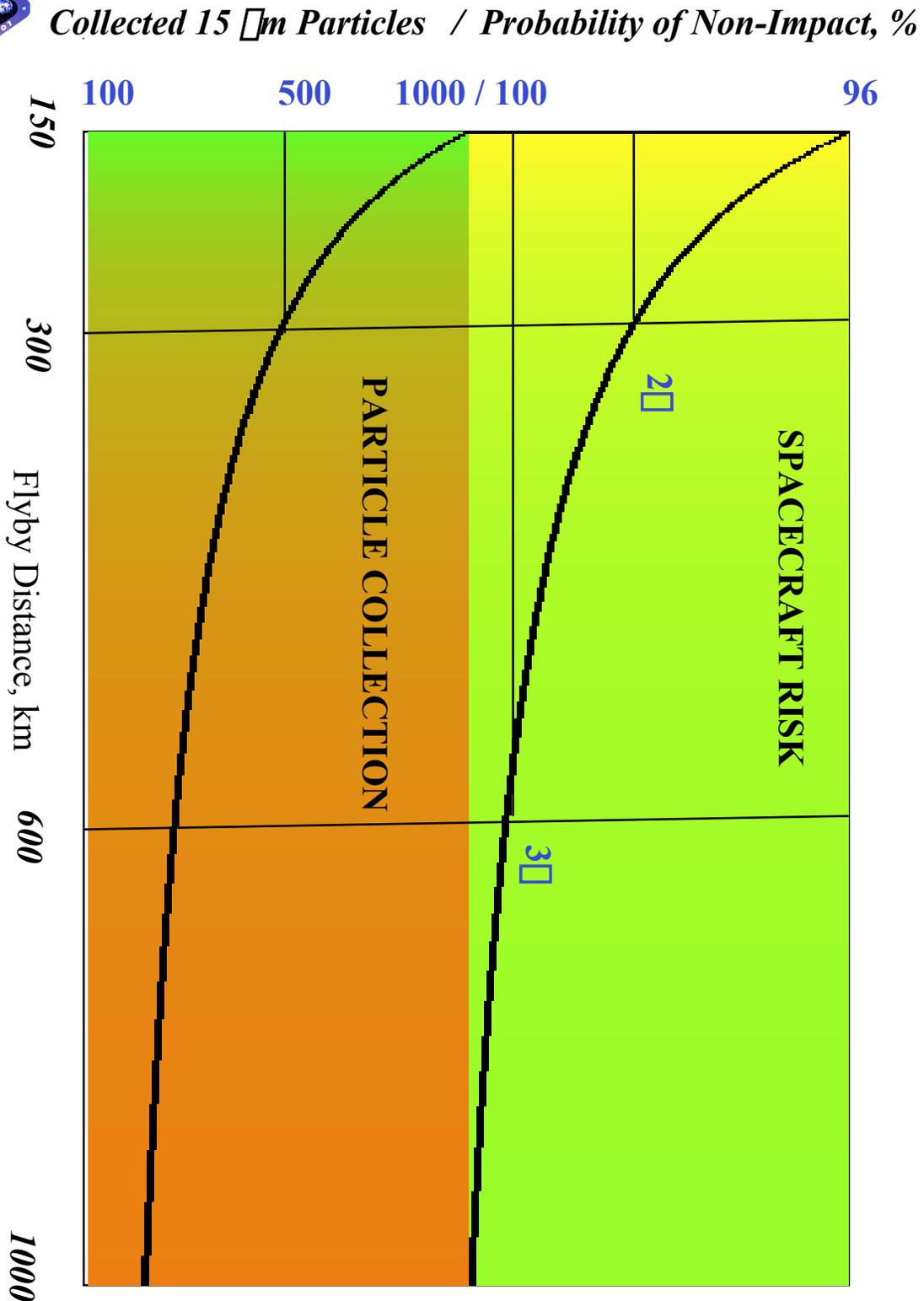
Flyby Distance Cannot be Further than 300 km to Meet Both Requirements





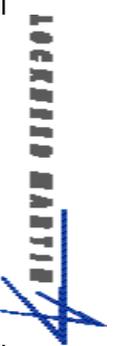
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Dust Collection and Spacecraft Risk Trade



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Probability of Large Particle Hit



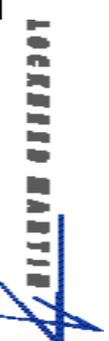
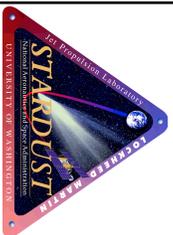
Spacecraft Element	Single Particle Probability of Not Penetrating Whipple Shield			
	PRD/FSRD Model	April 2003 Model		
Flyby Distance, km	150	150	300	600
Main Shield	0.9976	0.9738	0.9868	0.9934
S/A Shield	0.9979	0.9802	0.9900	0.9950
Wrist	0.9982	0.9977	0.9988	0.9994
Nav Cam	0.9981	0.9973	0.9987	0.9993
LVA	0.9998	0.9980	0.9990	0.9995
Total	0.9917	0.9478	0.9736	0.9867

3

<2

2

3



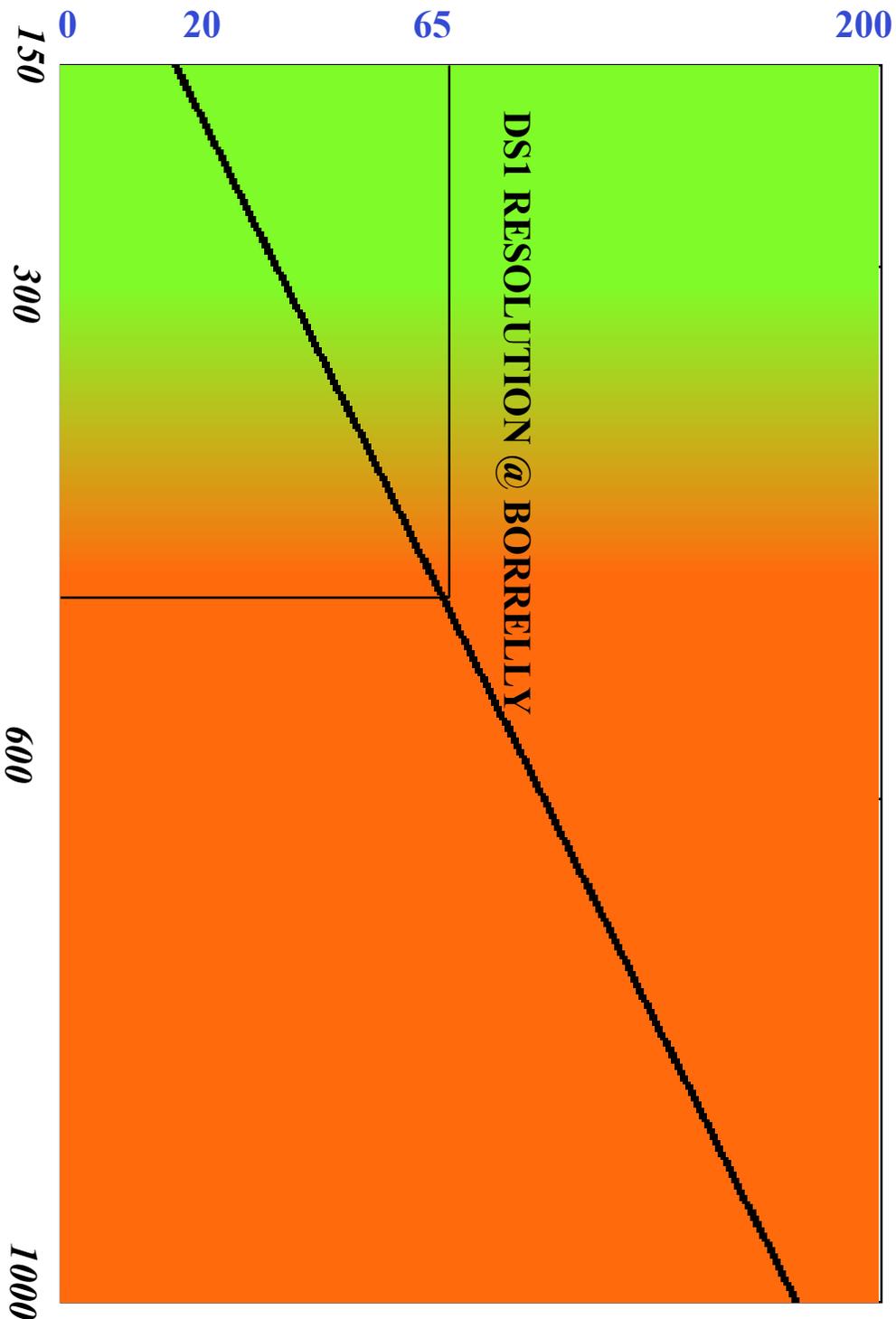


Wild 2 Encounter Expectations

Imaging Resolution (Secondary Science)



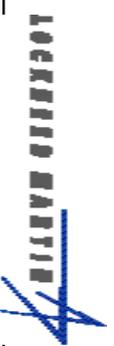
IMAGE RESOLUTION WITHOUT SMEAR, m



Flyby Distance, km

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Recommended Flyby Distance of 300 km



- Minor Modification Within Original Range of Acceptable Flyby Distances
- Provides Acceptable # of Dust Particles and Image Resolution
- Provides Probability of Impact by Large Particle $> 2 \square$
 - Consistant with Other Project Risks Designed to Cover $2 \square$ Dispersion
 - Fuel Loaded at Launch
 - Expected Success of 65 Images Containing the Nucleus
 - Encounter Design to Cover $2 \square$ of Time of Flight Uncertainty
 - Design of Annfrank Sequence
- Decreases Bank Turn Prior to Wild 2 Flyby which Increases Signal Strength of Carrier During Wild 2 Flyby Communications
- All Spacecraft (Giotto (2), VEGA, DS1) Survived Encounters with Comets
 - New STARDUST Dust Model Viewed as Safe Upper Limit
 - Similar Model Predicted DS1 Would Fail



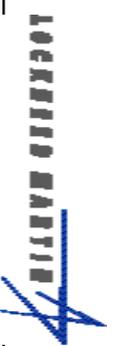
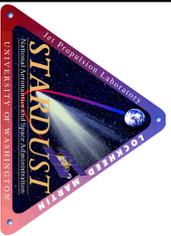


Wild 2 Encounter Expectations

Current Wild 2 Mission Success Criteria



4 Party Agreement (4/22/1996)	Party Agreemer 10/19/01	NASA Mission Success Criteria (1/27/1999)	Complete	Prime	Minimum	OR
Science Rqmt		Science Rqmt				
Primary Collect 1000 comet particles >15 microns	Same	Same	Same	Same		
Secondary Collect 100 interstellar particles >0.1 micron	Collect interstellar particles for 150 days	Collect interstellar particles for 150 days	Collect interstellar particles			
> 65 images with resolution at least 67 microrad per pixel within 2000km of comet nucleus through selected filters	Same	Same	At least 65 images of comet nucleus within 2000km			At least 25 images of comet nucleus within 2000km
In-situ particle analysis capable of resolving abundant elements in cometary solids	Same	Same	Collect 75% of science data available during cruise & encounter			Collect 50% of science data available during cruise & encounter
Tertiary In-situ particle analysis for interstellar & interplanetary dust	Same	Same				
Collect comet coma molecules	Same	Same				
Measure dust mass fluence, large particles and comet mass upper limit	Same	Same				
Dust flux measurement of 10 ⁻⁹ g to 1g particles	Same	Same				

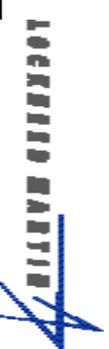
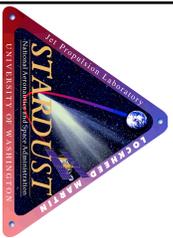




Recommended Minor Restructuring of Mission Success Criteria



OBJECTIVE	CURRENT	NEW
CIDA Observation	Continuous Around Encounter	NO CHANGE
DFMI Observations	Continuous Around Encounter	NO CHANGE
Radio Science	Mass and Integrated Dust Determination	NO CHANGE
High Rate Attitude	Detect Larger Particle Hits	NO CHANGE
Color Imaging	Obtain Low Resolution Image	REMOVE
“Giotto” Image	Play Back Extended Image Before Flyby (Was Not Probable)	NO CHANGE (Now Probable)
Image Location	65 Images Within 2,000 km	30 Within 2,000 km
Highest Resolution	No Requirement	> DS1 @ Borrelly
Particle Collection	1000 Particles > 15 μ m	>10 μ m
Volatile Collection	None	NO CHANGE
ISP Collection	Completed	NO CHANGE

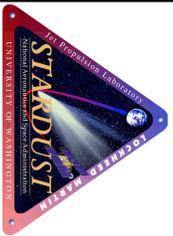




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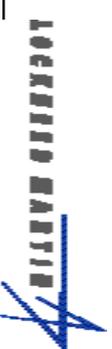


Backup Material



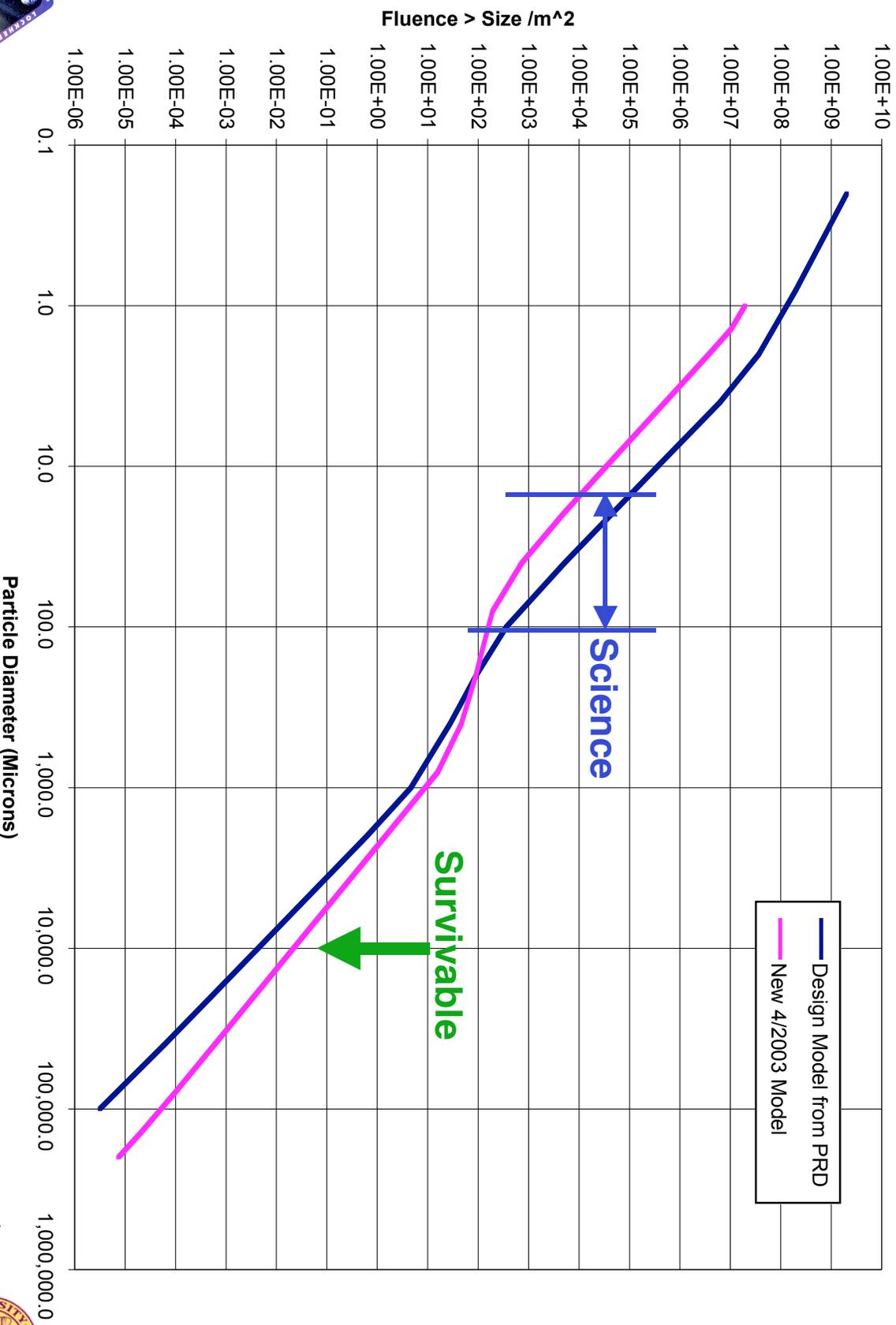
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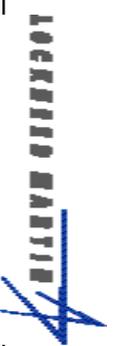


Wild 2 Encounter Expectations New vs Original Dust Flux Model



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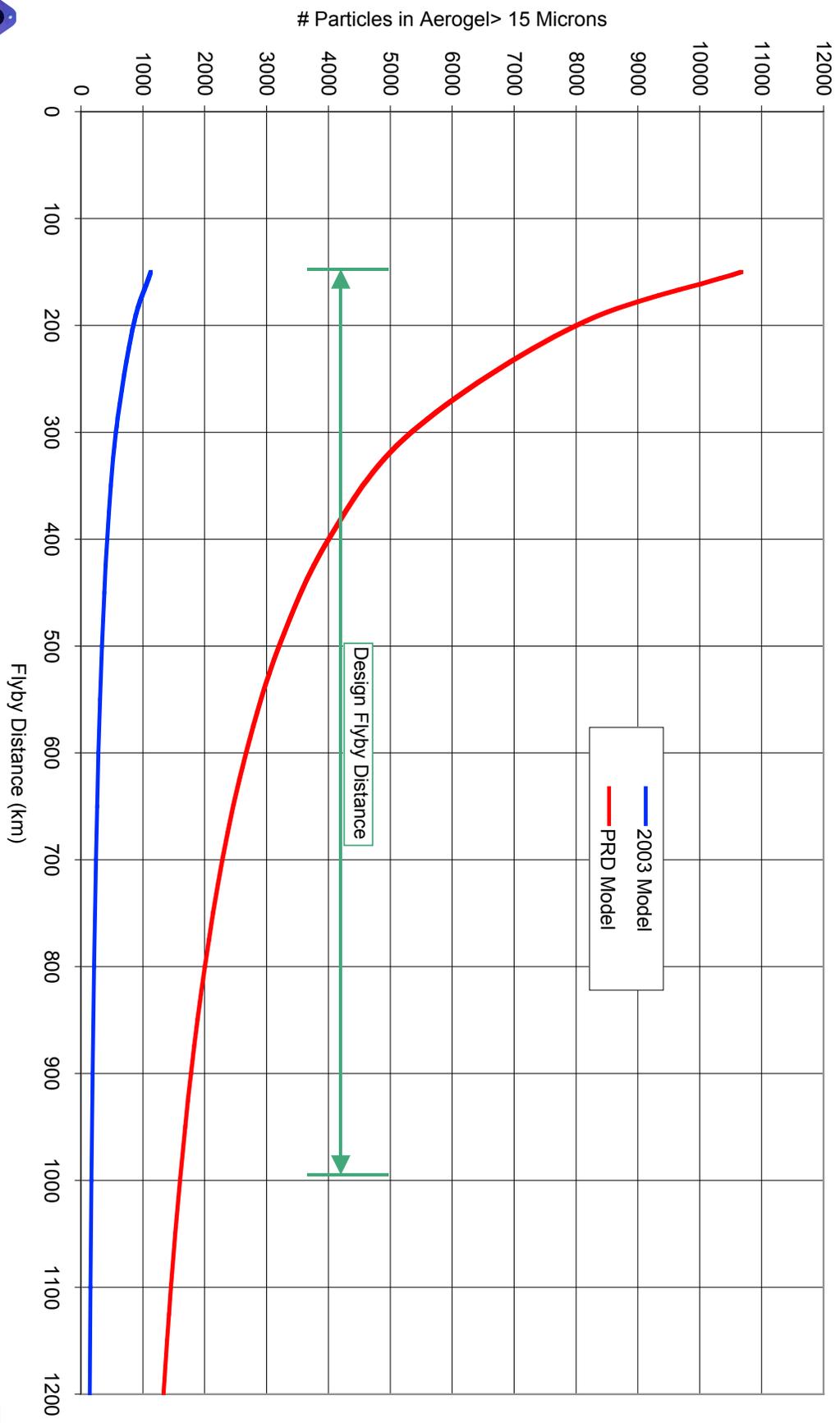


Wild 2 Encounter Expectations

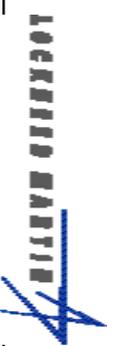
≥15 um Particles Collected vs Range



Number of Particles Collected in Aerogel



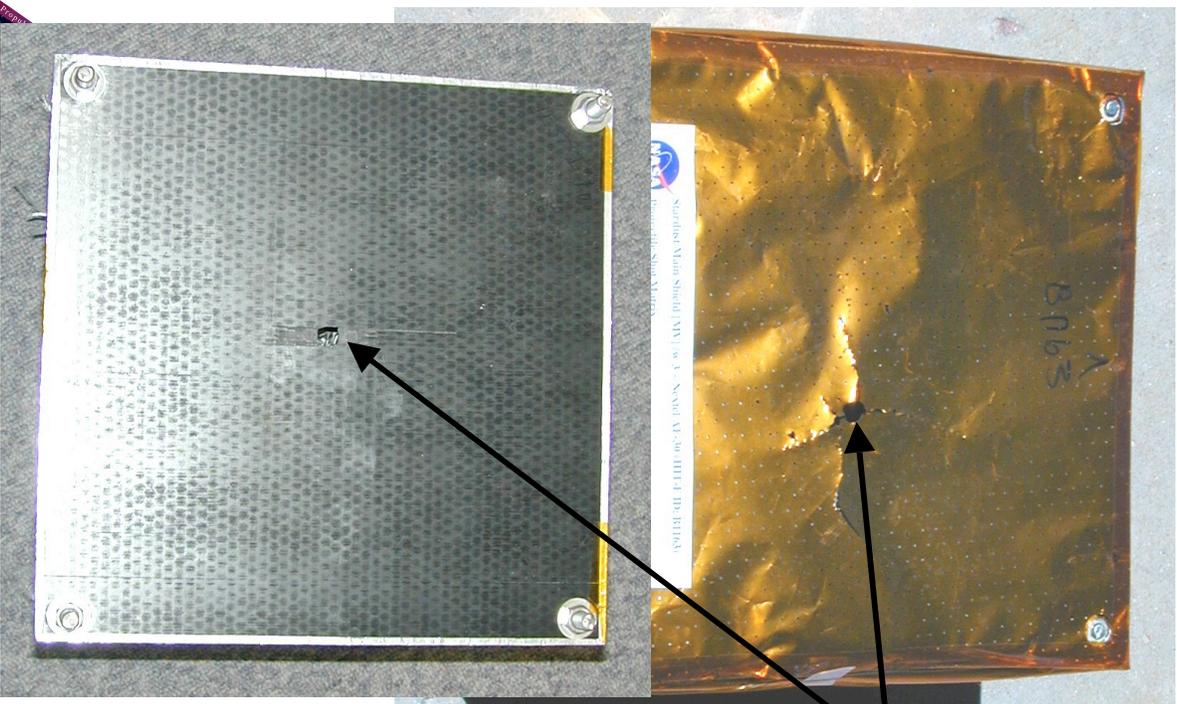
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Wild 2 Encounter Expectations

Whipple Shield Performance **JPL**

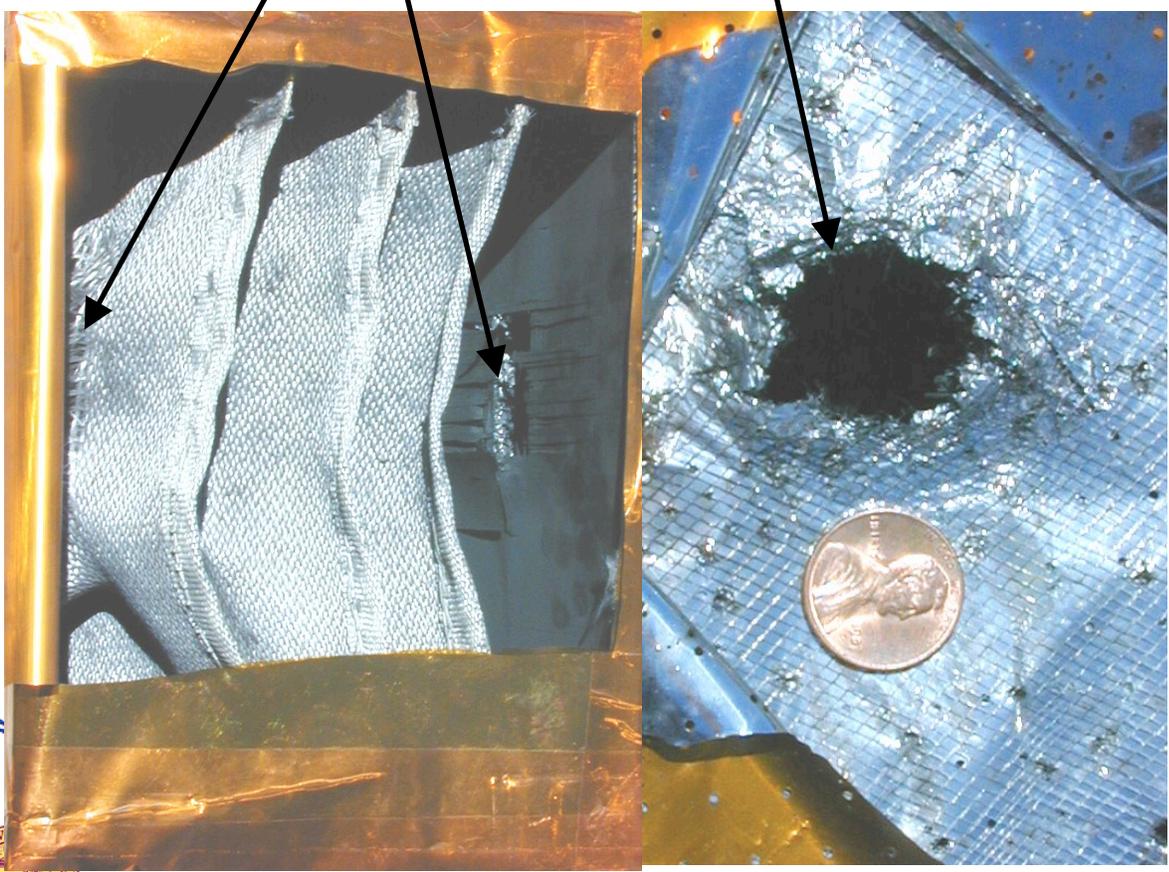


1 cm

2 cm

5 cm

11 cm



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LOCKHEED MARTIN

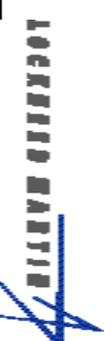
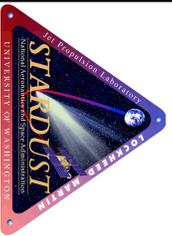




Sensitivity to Flyby Distance



- **Dust Collection Decreases by $1/r$**
- **S/C Hazard Decreases by $1/r$**
- **Imaging Resolution Decreases by $1/r^2$**
- **Bank Turn Decreases by $1/r$**
 - **Improves Carrier Signal Strength but not Sufficient to Obtain Meaningful Telemetry Rate**



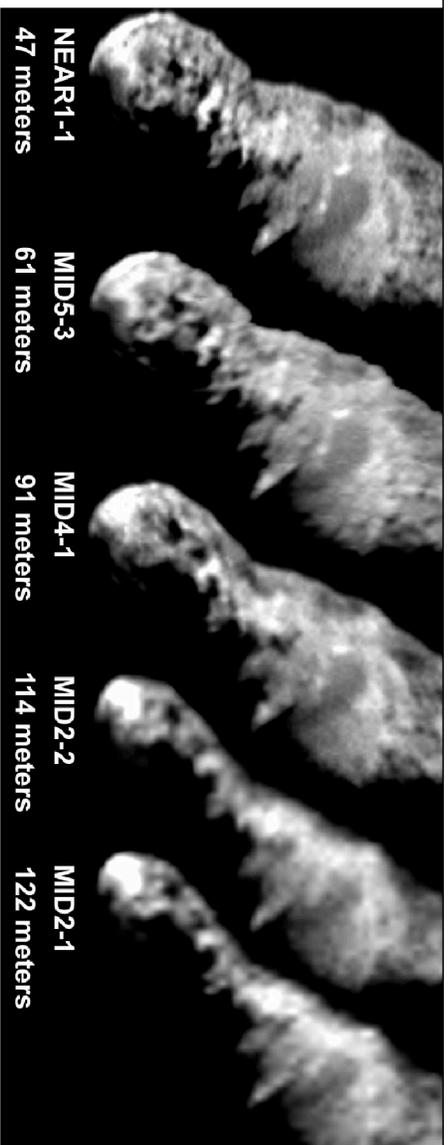
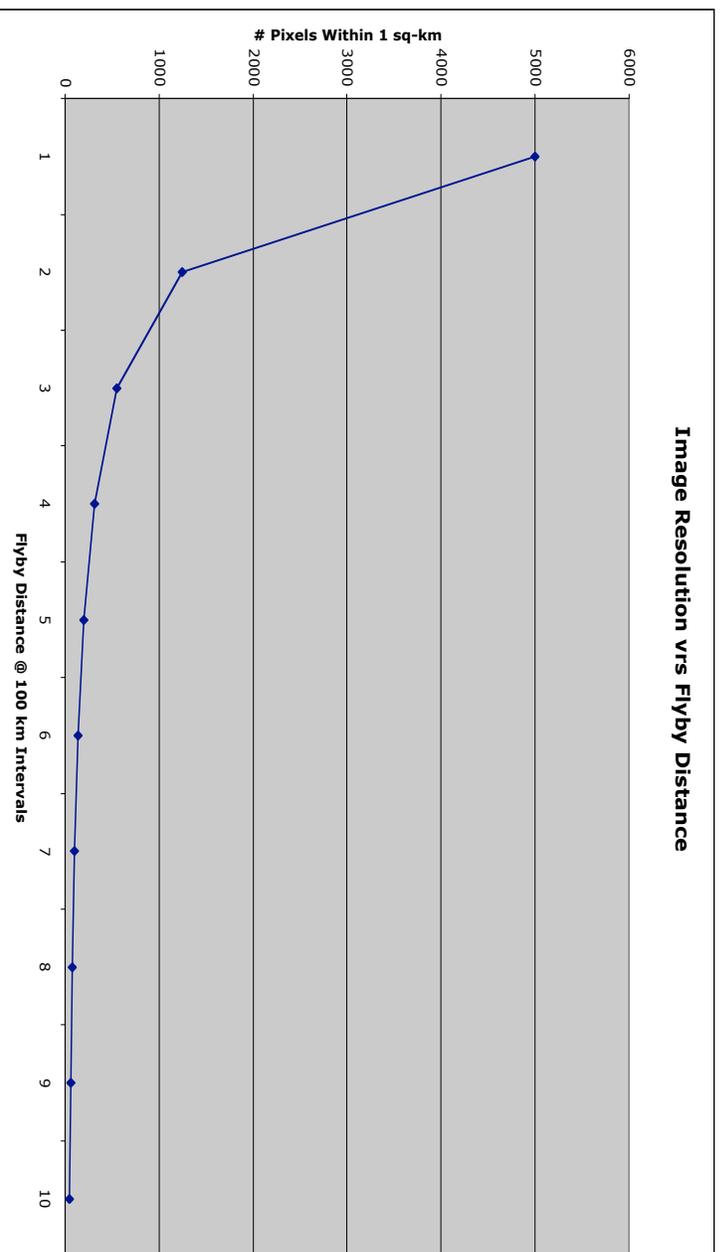


Wild 2 Encounter Expectations

Image Spatial Resolution



Image Resolution vrs Flyby Distance



NEAR1-1
47 meters

MID5-3
61 meters

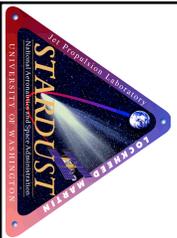
MID4-1
91 meters

MID2-2
114 meters

MID2-1
122 meters

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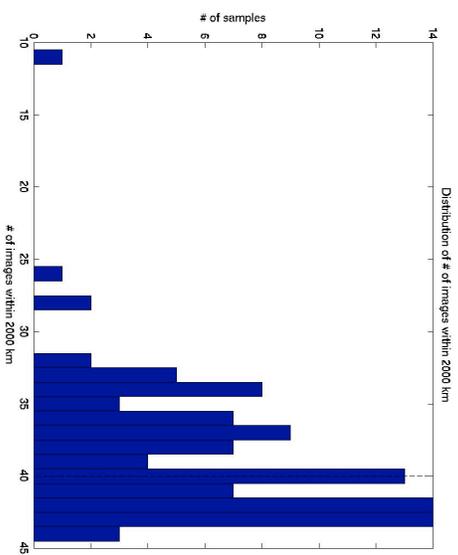




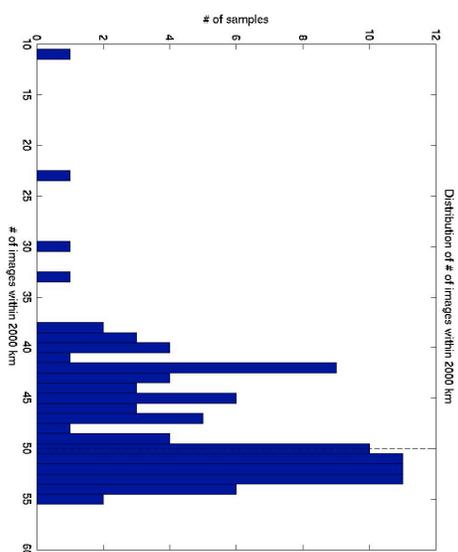
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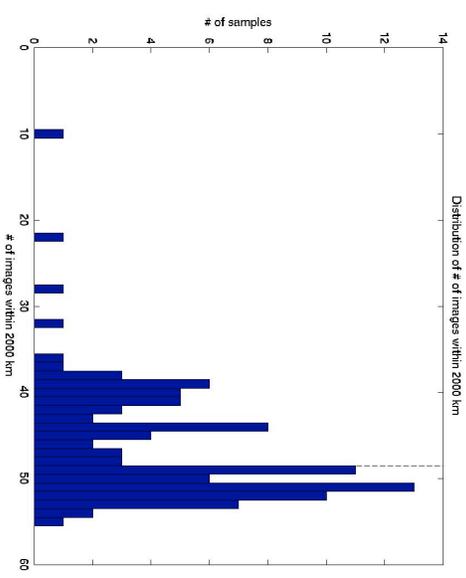
Probability of Imaging *Within 2,000 km*



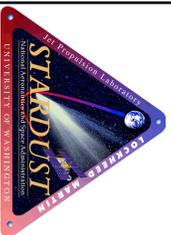
@ 150 km



@ 300 km

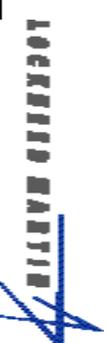


@ 600 km



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Communications During Wild 2 Encounter



- Nav Flyby Control Accuracy of 20 km (1□) Requires a Roll Turn of 7 deg (1□) to Align the Mirror Plane to the Trajectory Plane for a 150 km Flyby Distance
 - Probability of Loss of Telemetry < 6 % on MGA for ~ 10 Minutes*
 - Probability of Loss of Carrier < 0.5 % on MGA for ~ 10 Minutes*
 - within coma for > 6 hours; probability scales linearly w/ flyby distance
- Low Rate Telemetry Offers no Gain Over Carrier Only

Stardust Wild-2 Encounter Antenna Offpoints vs. Downlink AGC (downlink bits/sec)

