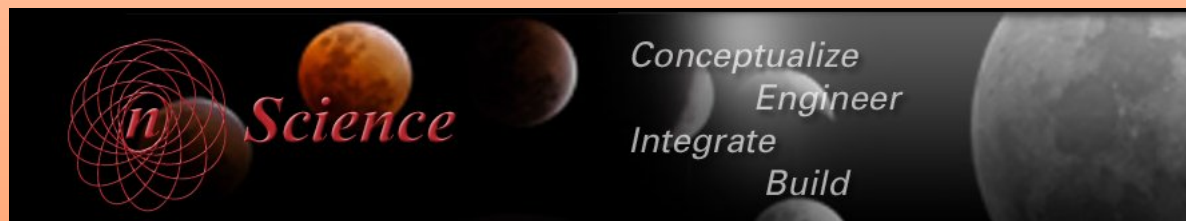




INTRO to HUMMINGBIRDS & CHARM



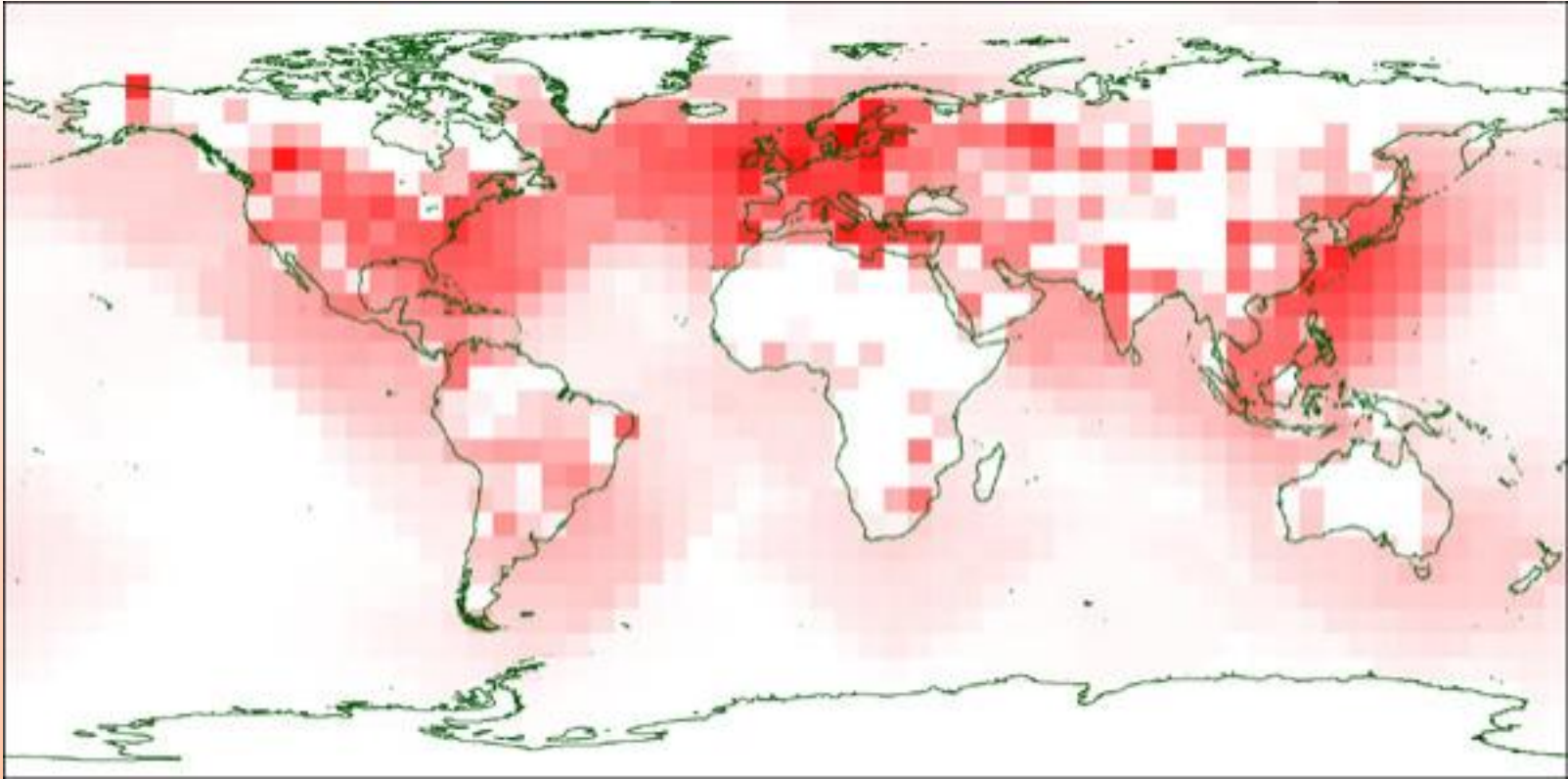
HUMMINGBIRDS/CHARM

**Asteroid/Comet Engineering Science Service(ACCESS)
Missions**

**Asteroid/Comet Collaborative Engineering
Science Service
(ACCESS)
Missions**



HUMMINGBIRDS/CHARM



NEO/NEA Impact Damage Potential

- NOT A Threat,,,Just Something WE HAVE TO “TEND TO”
- Follow our Collective Common Sense,,,Follow a SIMPLE GUIDANCE

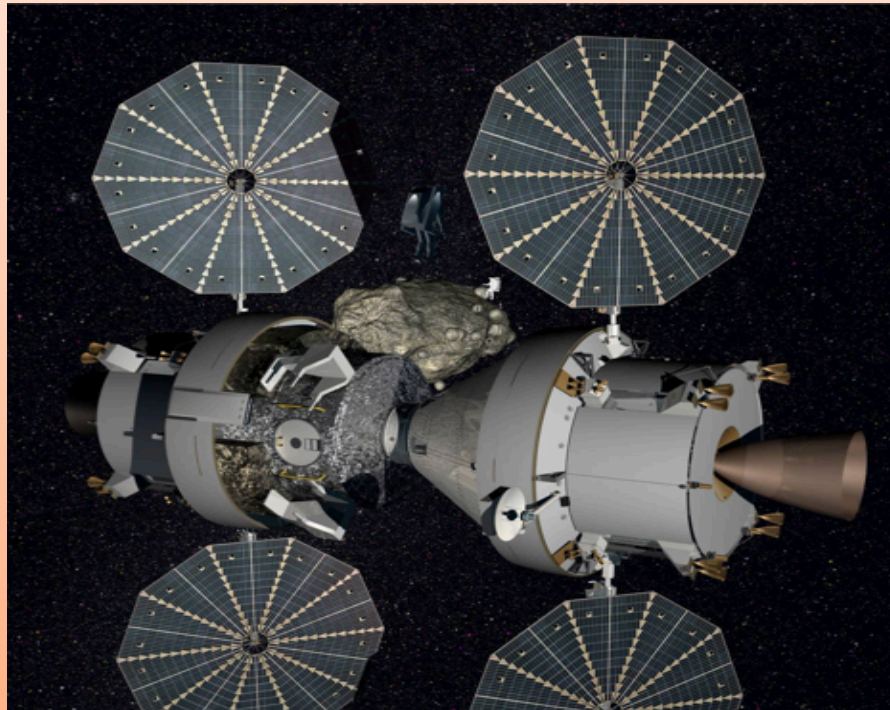
OBSERVE-TOUCH-EARLY-OFTEN



HUMMINGBIRDS/CHARM

Question 1:

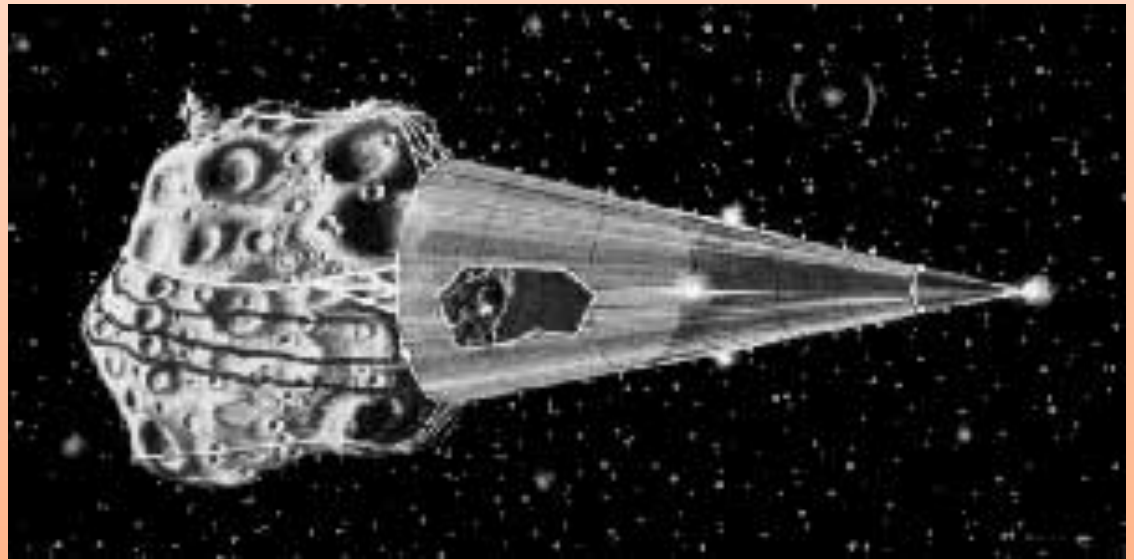
On What Date is the NASA
Manned Asteroid Mission
“A GO”??



HUMMINGBIRDS/CHARM

Question 2:

On What Date Do We
Begin Real Asteroidal
Material Utilization?



HUMMINGBIRDS/CHARM

Question 3:

On What Date Are We
Capable of Providing
a Defensive
Capability??



HUMMINGBIRDS/CHARM

Question 4:
On What Date???



HUMMINGBIRDS/CHARM

HC / Started as Set of “WHAT IFs”

WHAT IF; NASA Manned Mission was Going in 2025-2030 Timeframe

Drives a timeline of 12 to 17 years in which to accomplish these “interviews”

What IF; We Needed to get to a Multitude of Targets

What’s the Right Number??

We Initially “Baselined” 10 Targets (Total Guess)

Continued Discussion with the “Experts” on Number of Targets

A Number of Responses Were Received

As Many As We Can Reach,,,

A Better Number 24,,,

A MINIMUM Number of Targets,,12

And, These shouldn’t be simply “FLY-BYs”, We want to Stay!

What IF; We Needed to Conduct Individual Missions to 12 Targets in a Window of 12 to 17 Years

How would this be accomplished??



HUMMINGBIRDS/CHARM

HC / OUR GUIDANCE

OBSERVE
TOUCH
EARLY
OFTEN



HUMMINGBIRDS/CHARM

HC / OUR GUIDANCE Drives our Approach

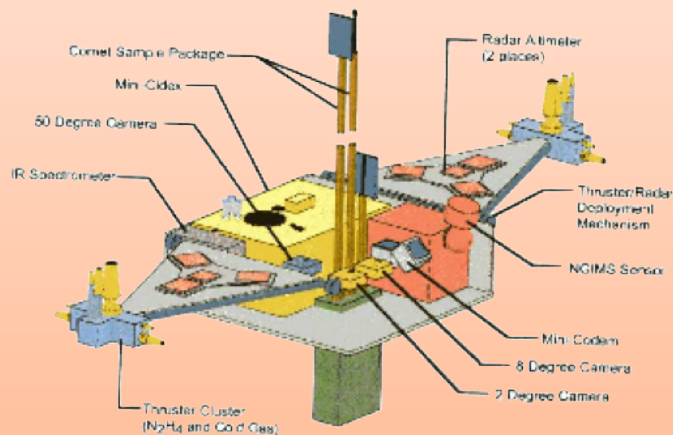
Overwhelming
Cost
Effective
(OCE)



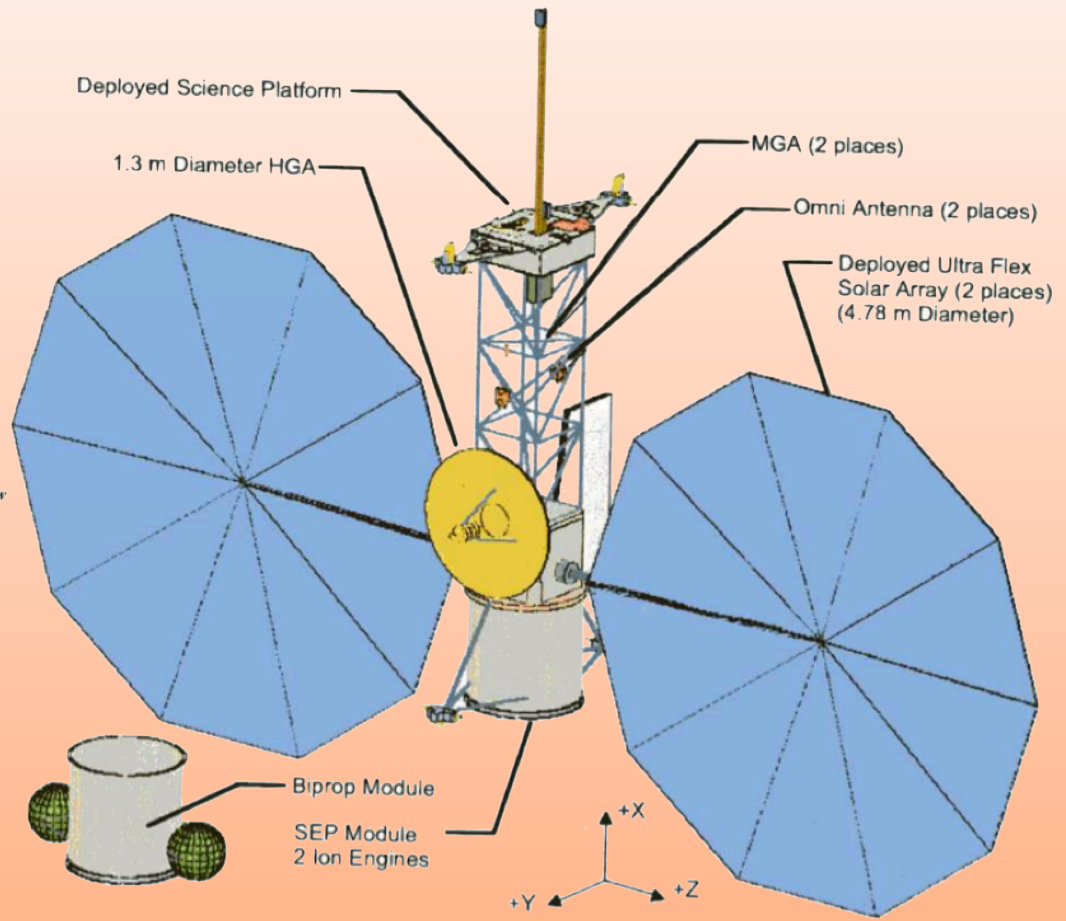
HUMMINGBIRDS Background

A Little History – The Original HUMMINGBIRD

Long Ago...



Science Deck



Spacecraft



HUMMINGBIRDS/CHARM Backgroud

Evolution: Hummingbird-TO-HummingbirdS

- What was Right about Hummingbird “Then”:

Hummingbird would have provided much in the way of the “right science” and information useful today

- What’ s Right about Hummingbirds/CHARM “Now”:

Hummingbird was a “One-Off”

-HC is a “many-off” concept , Production MODE

Hummingbird Provided Great Science, but only “One” Target

-HC, ”Many-Off”, Multiple Targets

Hummingbird Spacecraft and Systems too Complex

-HC, Simplification Across ALL Systems

Hummingbird Autonomy: Autonomous Operation was in Infancy

-Capabilities have Advanced Significantly,,,

Hummingbird Proximity Operations: PO was a relatively new Topic

-Capabilities have Advanced Significantly,,,



HUMMINGBIRDS/CHARM Background

NEOs/NEAs – What we know



HUMMINGBIRDS/CHARM Background

NEOs/NEAs – What we Don't Know



HUMMINGBIRDS / CHARM

Rational

- Address the Highest Priorities in Asteroid and Cometary Science
- Rendezvous, Orbit, Characterize via Multiple Descents & Observations of Various Targets
- Meets the needs of the Science Community
 - Planetary Geochemistry,
 - Atmospheric Science,
 - AstroPhysics,
 - CosmoChemistry,
 - Space Physics, Exobiology,
 - Planetary Protection Systems,
 - Solar System Evolution,



HUMMINGBIRDS / CHARM

Rational

- **Intense Interest from the Public and Lay Scientist**

 - Outstanding Public Outreach Potential

 - Outstanding Opportunities in STEM Programs

- **Critical Interest for Planetary Protection Plan**

 - Absolutely “Must Have” in putting together any reasonable Protection Scheme

- **Logical Fit with the NASA xPRP, xSCOUT Paradigms**

 - Assumed that these Programs “survived” (which they haven’ t) and

 - Assumed “Some Level” of NASA Engagement

- **Logical Fit with New Interest in Asteroid Precursor Missions**

 - Note the new APL NextGenNEAR Concept

 - Note the so-far “un-titled” Something that NASA Exploration Systems Is talking about



HUMMINGBIRDS / CHARM

Rational

- Logical Fit with the New Surface-To-Surface Systems Concept

Similar in Approach to XTV/Common Lander Mission Models

-Critically Important to Future Missions

Key to Understanding Of Earth Crossing Targets

-Lastly, Absolutely Necessary to Future Missions

NOTE the Lockheed PLYMOUTH ROCK Mission

NOTE the “Asteroid Next” Effort

NEO/NEA/COMET Sample Returns

HUMMINGBIRDS / CHARM

“Plym Rock” Precursor Missions,,,

“Asteroid Next” Precursor Missions,,,

“Sample Return” Precursor Missions,,,



HUMMINGBIRDS / CHARM

Objectives

-Globally Determine Target Characteristics

Physical, Elemental/Mineral / Molecular/Isotopic
Surface Morphologies
Ground Truth for Existing Data and Models

-Provide Detail Visuals at Target

Imagining Over Entire Target
Variety of Stand-Off Distances / Separations Available
between the 2 Vehicles and the Target Body
Imaging of the Surface TAGS by ObsCOMM

-Characterize Composition and Processes at Target

Via both Visual and Tactile Systems

-Target Composition and Structure are TOP Priorities

Visual / Tactile / Radar / Instrument Suite



HUMMINGBIRDS / CHARM

Drivers in Design/Methods

Overwhelmingly Cost Effective (OCE)

LV Cost - FALCON 9 (Equivalents,,, "OR BETTER")

Simple Bus Designs/Same Design for each SC

Low Cost to Allow for "Many-Offs"

Reach Max # of Targets

"TWO" Vehicles to Selected Targets (thus the CHARM)

TOUCH & GO Vehicle/TAGS (Sampling, Instruments)

Observer and Prime Comm/ObsCOMM (Instruments)

ROLE PLAYING Concept: the Surrogate Astronaut

Reduced Complexity Across ALL Systems/Subsystems

Minimize # of Deployments, Mechanisms

Reduced Complexity in Instruments

Simple TAGS Sampling

Single-string Hummingbirds

2 Birds Bring Redundancy



HUMMINGBIRDS / CHARM

HUMMINGBIRD Touch & Go Sampler TAGS Vehicle

TAG,,Your It!!



HUMMINGBIRDS / CHARM

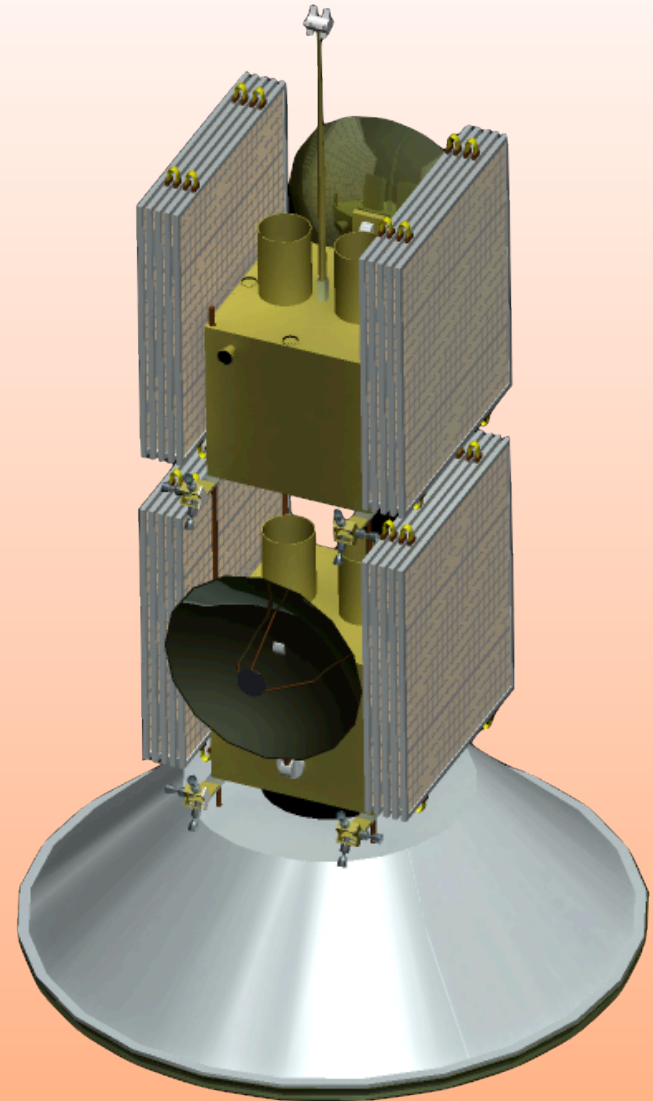
HUMMINGBIRD Observer/Communications ObsComm Vehicle



HUMMINGBIRDS / CHARM

Hummingbird / Charm Stack

- Launch Config Options
- Stacking Options
- Fits Various LV Envelopes
- other???



HUMMINGBIRDS / CHARM

HUMMINBIRDS/CHARM Instruments

-HC Provides the BASE INSTRUMENT SUITE

-MULTIPLE IMAGERS

-RADAR

-2 Vehicle Transmission Radar System

-Contact Devices

-Contact Samplers

-HC Provides SCIENCE INSTRUMENT SUITE OPTIONS

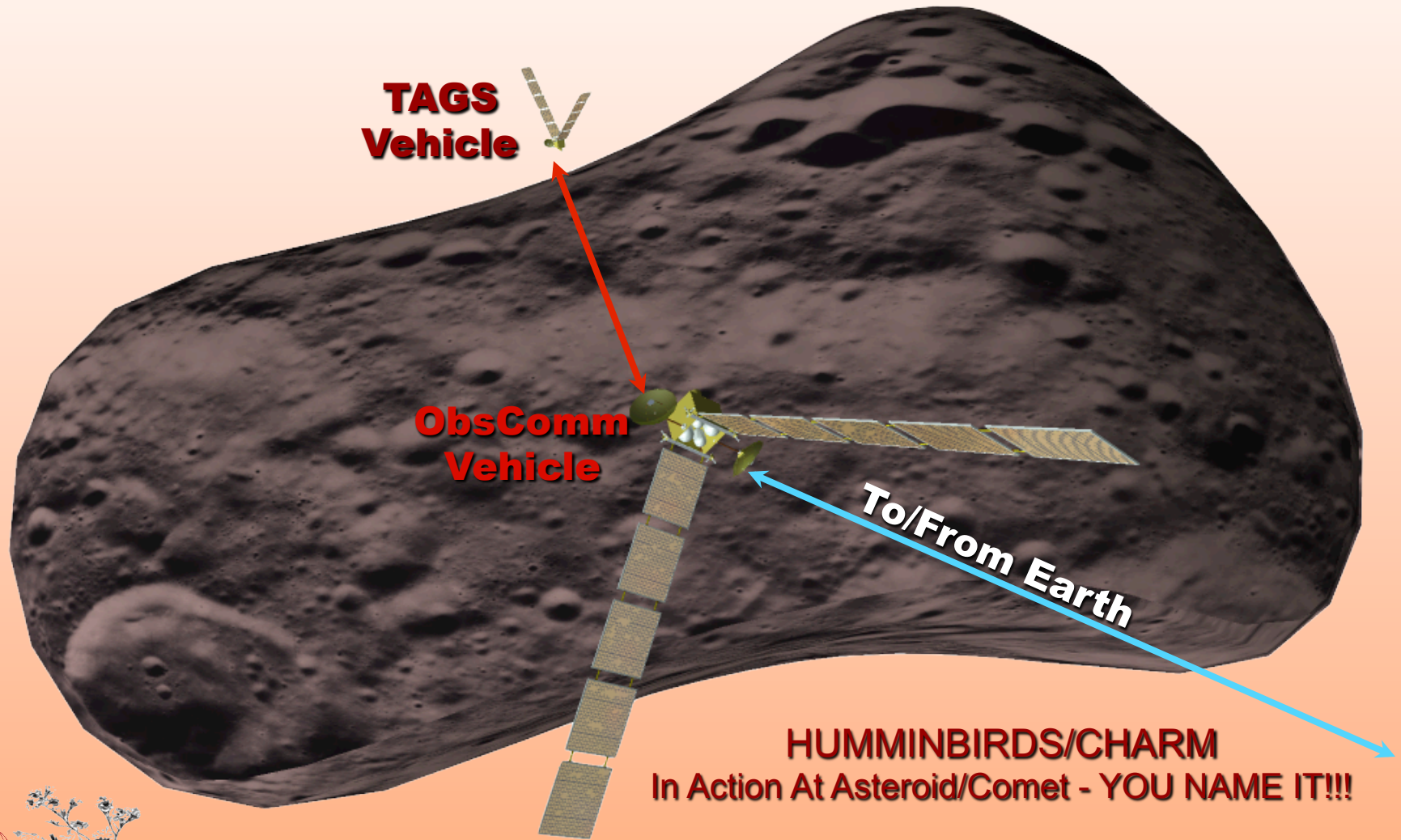
-Dependent on Target

-Asteroid Suite Options

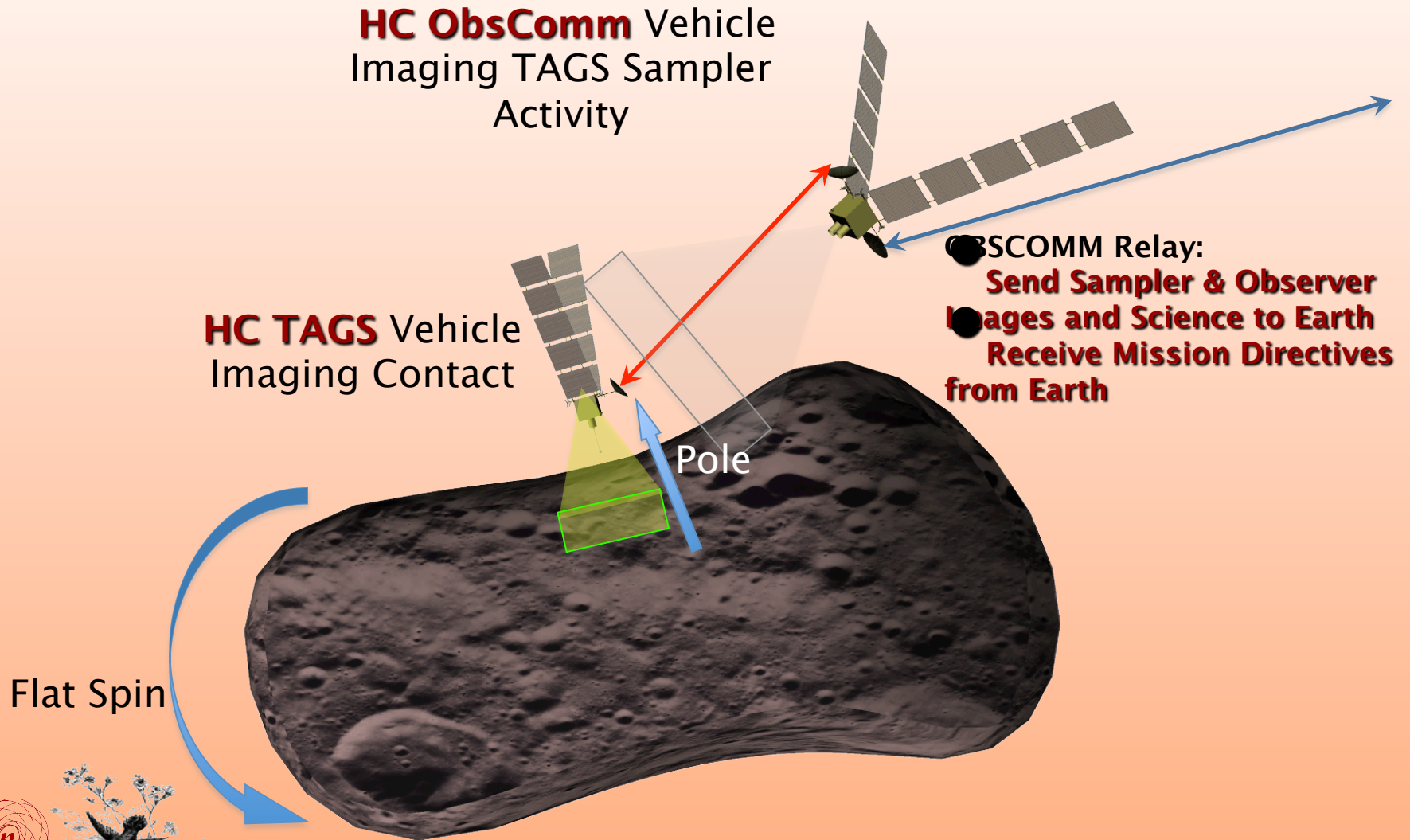
-Comet Suite Options



HUMMINGBIRDS / CHARM



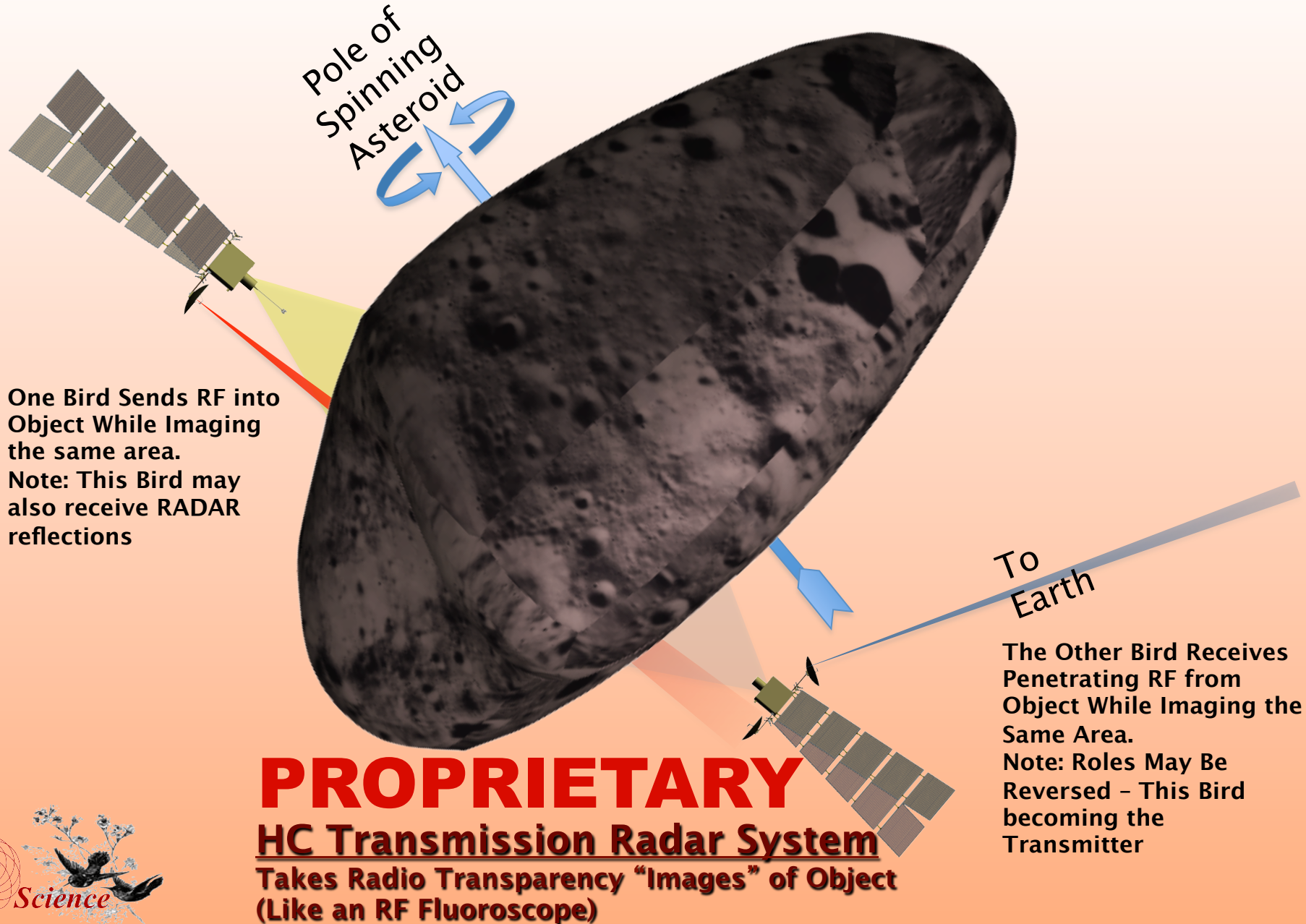
HUMMINGBIRDS / CHARM



HC – Typical Engagement at Asteroid

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HUMMINGBIRDS / CHARM



HUMMINGBIRDS / CHARM

TEAM “Taxonomy” (NOTIONAL)



NOTE:

**THERE ARE NO OFFICIAL
TEAMING AGREEMENTS
With ANY Potential
Players/Partners
At this Time**



HUMMINGBIRDS / CHARM

TEAM “Taxonomy” (NOTIONAL)



N-Science Corp
SouthWest Research
Colorado School of Mines
CSM Center for Space Resources
SpaceX
United Launch Alliance
BroadReach Engineering
Ball Aerospace
ABSL Space
Honeybee Robotics
Space Science Institute
Planetary Science Institute
Mountain Man Aerospace
New Mexico Tech
Denver Museum of Nature & Science
SETI
UCLA
Technology Applications, Inc
HawkSpace
JETS I Company



HUMMINGBIRDS / CHARM

COST

MODELS that Lower Cost

- XTV/Common Lander

-Targets Cost similar to that presented by NASA xSCOUTs

- PlanetIQ / CICERO PROGRAM

-Independent Program to provide Climate and Weather Data

-A “Commercial” Program

-Planetary Resources, Inc.

-Independent Program to ultimately provide Asteroidal Materials

-Rideshares (Lots of them out there now)



HUMMINGBIRDS / CHARM

The BIG Question : Funding

Options/Mechanisms

- Independent Funding (ala PRI)

-HC May be Attractive to Investors with Similar Interest in Material Utilization

- Donations Approach/Philanthropy

-Not Likely, but Possible (being considered in other efforts)

- NASA

-Possible, but Requires a New Routine
(Not, Discovery, New Frontiers,,,))

- Partnerships

-Public/Private Partnerships, Space Act Agreements, etc

- FEMA



HUMMINGBIRDS / CHARM

The BIG Question : Funding

FUNDING HC : Some Considerations



- JOBS / STEM / EPO

Consider the number of entities in Colorado that might be involved

- Cost effective programs of the type envisioned by HC will have Carry Over into other Program Areas

eg, MARS, LUNAR, DoD, etc

- The NASA budget is not going to be pleasant for **Science & Exploration**

All the more reason to fund studies of
Overwhelmingly Cost Effective (OCE)
Programs

- Keeping the US in the Lead in NEOs/NEAs

EU is funding studies on project called

NEOshield,,, \$1.5M/year. Funding 13 European entities



HUMMINGBIRDS / CHARM

WHAT' s NEXT / HC MISSION SCENARIOS

Continued Mission Studies and Trades

-MODES of OPERATION/ Are we “On-Station”

- Ground: Could the HC vehicles be ready to fly on a moments notice, in a Responsive Space style program
- On Orbit: Are the HC vehicles “pre-positioned” on orbit
- Implications for Cost; Lot Buys and Builds,??

-MODES of OPERATION/ Are we Pitching or Catching
and the Requirements Drivers:

**Pitching: HC Targets Are “pre-Selected” NEOs/NEAs
and not necessarily “Close Passers”
(within some distance,,??)**

**Catching: HC Targets Are “unknown” , “Close Passers” ,
for example, the 2 recent unknown close passes back
in May**



HUMMINGBIRDS / CHARM

WHAT' s NEXT / HC MISSION SCENARIOS

Continued Mission Studies and Trades

-MODES of OPERATION/ AUTONOMY

- HC has significant Autonomous Operations Requirements**
- Formation/De-Formation, 3 Body Activities, etc.**
- HC Vehicles must “learn from” the Environment at the Target**

-MODES of OPERATION/ Instrumentation

- Instrumentation and Instrumentation Suites that fit
OCE Model and provide “best knowledge” on the dollar**

-MODES of OPERATION/ Contact Mechanics and Devices

- Contact Devices that fit the OCE Model**

-MODES of OPERATION/ SAMPLING

- ”BEST Fit” Sampling, That Fits the OCE Model**

-SYSTEMS : Power, Comm, Propulsion, Data Handling,,,,,



HUMMINGBIRDS / CHARM

WHAT' s NEXT / HC MISSION SCENARIOS

**We will Provide a Complete HC Missions Plan and Outline
“Targeted” for AUGUST 1 of this Year**

-Our Plan Will Include a Targets List for potential NEO/NEA
Targets, Cost Targets, Notional Schedule, etc.

**Why August 1; This is the Date for the Planned Release of the
Small Bodies Assessment Group (SBAG) charter for a new
Small Bodies Science Institute (SBSI).**



HUMMINGBIRDS / CHARM

HC - As a “COLORADO CONCEPT” (notional)



EVERYTHING REQUIRED
In
MEETING THE NEED
IS
RIGHT HERE
IN **COLORADO**



HUMMINGBIRDS / CHARM

HC - A “COLORADO CONCEPT”



LAUNCH VEHICLE
SPACECRAFT
DESIGN
SYSTEMS
AVIONICS
ROBOTICS
INSTRUMENTS
OPERATIONS
SCIENCE
DATA HANDLING
EPO
STEM
,,,and so on



HUMMINGBIRDS / CHARM

HC - A “COLORADO CONEPT”



N-Science Corp
BroadReach Engineering
Technology Applications Inc.
Mountain Man Aerospace
BALL Aerospace
SouthWest Research Inc.
United Launch Alliance
Space Science Institute
Honeybee Robotics
Lockheed Martin
Sierra Nevada
ABSL Space
Colorado School of Mines
Center for Space Resources
University of Colorado
University of Denver
,,,and so on



HUMMINGBIRDS / CHARM

HC - A “COLORADO CONEPT”



The COLORADO CENTERED
CONCEPT,,,perhaps leads
“naturally” to A Bigger Picture:

The focus on NEO/NEA programs in
Colorado “COULD” lead,
Naturally, to a “centralizing theme” ,

IE, COLORADO is a
“NASA CENTER”

-Note:

This idea is not new. This has been mentioned from
time to time at various meetings of CAMT, ACE, etc.
The problem is just that,,,it is talked about without any
real ideas as to how to bring that together.

The “FOCUS” is required.



HUMMINGBIRDS / CHARM

HC - A “COLORADO CONCEPT”

Each NASA CENTER has a
“Central Theme:

NASA Goddard - Astrophysics & Astronomy

NASA Glenn - Propulsion & Cryo

NASA Marshall - Propulsion

NASA KSC - Launch

NASA JSC - Human Space Flight

NASA JPL - Planetary Missions

& NOW,,,perhaps, Colorado has a center, THE
NASA Shoemaker Space Flight Center- NEOs/
NEAs

(perhaps name it after Eugene Shoemaker)



HUMMINGBIRDS / CHARM

HC - A “COLORADO CONCEPT”

The NASA CENTER-

NASA Shoemaker Space Flight Center

Concentration on NEOs/NEAs

Provides a “rally point” for Activities:

Companies

Science Institutions

CAMT

ACE

Space ACT Agreements

EPO

STEM

,,,and so on



HC is
YOUR
MISSION,,,

,,,should we decide to accept it



HUMMINGBIRDS/CHARM

HC / It's Not Ours,,,It's YOURS

HC is the Program for the COMMUNITY of COMMUNITIES

- the SCIENTIST Seeking to Complete the Business of NEO/NEA Characterization & “Catalog”,,,the Ground Truth
- the ENGINEERS Working New NEO/NEA Mission ; Sample Returns, Manned Missions, etc.
- the ASTRONAUTS Who Will Work in the NEO/NEA Environment
- the PLANETARY DEFENDERS Seeking to Understand “Best Methods” and Deflection Strategies
- the STRATEGIST Working to Minimize “Impact” Impact,,,Economic Recovery,,,etc.
- Finally, the person “Paying the Bills”



HUMMINGBIRDS/CHARM : Summary

HUMMINGBIRDS / CHARM Rational

Logical Fit with NASA Asteroid Mission “Discussions”

Manned Asteroid Mission Plans (2025 Target, Plym Rock,?)

Intense Interest from the Public and Lay Scientist

Outstanding Public Outreach Potential

Outstanding Opportunities in STEM Programs

Economic Interest

Solar System Science

Critical Interest for Planetary Protection Plan

Absolutely “Must Have” in putting together any

Reasonable Concepts (with half a chance)

Logical Fit with New Interest in Asteroid Precursor Missions

Survey Missions (without Questions Required)

TargetNEO/Small Bodies Assessment Group (SBAG)

SURVEY MISSIONS

THE URGENCY FACTOR

HUMMINGBIRDS / CHARM “GUIDANCE”

OBSERVE-TOUCH-EARLY-OFTEN

HUMMINGBIRDS / CHARM Objectives

Globally Determine Target Characteristics

Physical, Elemental/Mineral//Molecular/Isotopic

Provide Detail Visuals at Target

Imaging Over Entire Target

Variety of Stand-Off Distances/Separations Available

between the 2 Vehicles and the Target Body

Imaging of the Surface TAGS by ObsCOMM

Characterize Composition and Processes at Target

Via both Visual and Tactile Systems

Target Composition and Structure are TOP Priorities

Visual/Tactile/Radar/Instrument Suite

HUMMINGBIRDS / CHARM Drivers in Design/Methods

Overwhelmingly Cost Effective (OCE)

LV Cost - FALCON 9 (or optional)

Simple Bus Designs/Same Design for each SC

Low Cost to Allow for “Many-Offs”

Reach Max # of Targets

“TWO” Vehicles to Selected Targets (thus the CHARM)

TOUCH & GO Vehicle/TAGS (Sampling, Instruments)

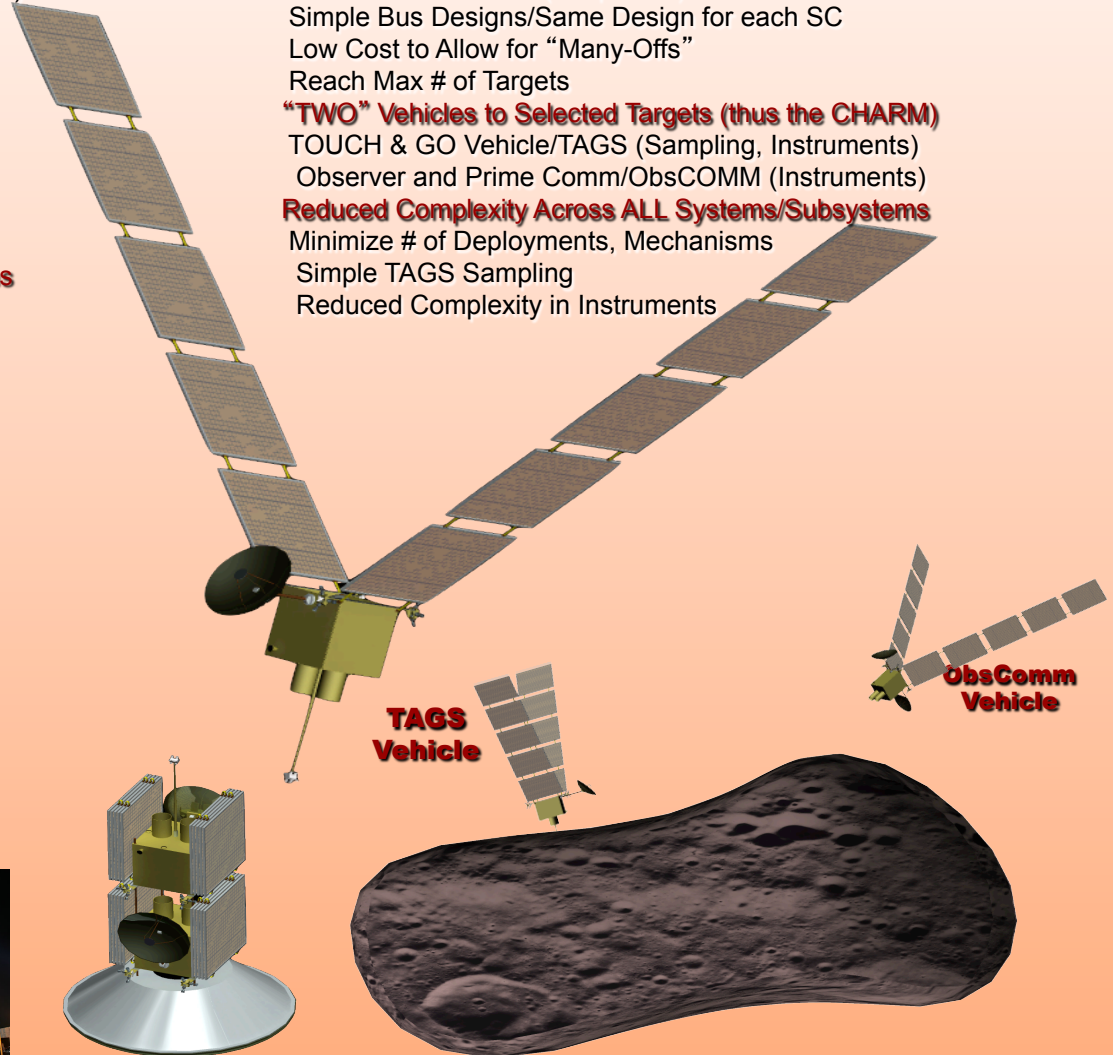
Observer and Prime Comm/ObsCOMM (Instruments)

Reduced Complexity Across ALL Systems/Subsystems

Minimize # of Deployments, Mechanisms

Simple TAGS Sampling

Reduced Complexity in Instruments



FINAL THOUGHTs

If We Don't Get This Right,
The Rest is
Just A Conversation,,,

(not my quote,,,forget where I heard it)

SEE YOU AT
SMALL BODIES ASSESSMENT GROUP
MEETING 7
July 10-12, Pasadena



HUMMINGBIRDS / CHARM



**Thanks MUCH,
More to Come!!!**

