
THE IMPORTANCE OF CONTINUING SOLAR SYSTEM-WIDE IMPACT CRATER STUDIES

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presentation for the Decadal Survey Panel

26 February, 2021

dedicated to Nadine G. Barlow (1958~2020)

The Motivation Statement

Impact craters studies are a fundamental part of nearly all solid body exploration across the Solar System.

The Next Decade

Continued investigations
of impact craters
should be a key component for
all future planetary missions ...

... and R&A funding should be allocated for
impact crater and related studies, including
observational, field work, laboratory, and
computer simulations.

Why Impact Craters Are Important

- 🚀 Impact crater populations are directly relatable to impactor populations that formed them (and are easier to see).
- 🚀 Impact craters are a direct proxy for ages of solid surfaces.
- 🚀 Impact craters excavate into planetary crusts, allowing us to see stratigraphy, composition, and history.
- 🚀 Impact crater shape is controlled by target strength, allowing us to see differences in strength and hidden faults.
- 🚀 Ground-truthing (Earth field work) allows testing laboratory and computer models: If we cannot accurately simulate a crater, we do not understand how they form and are modified.
- 🚀 Those simulations tell us what physics and processes are important.

**Including Funding for
Crater Studies in
Future Missions**

Studies via Mission Flybys

- 🚀 Allows good imaging of ~50% of a target.
- 🚀 Allows some stereo images for topography.
- 🚀 Use nested approach to study large dynamic range of sizes.
- 🔥 Not ideal, but provides extremely useful data for a wide range of studies, including one of the most *impactful* and wide-ranging results from *New Horizons: The size-frequency distribution of Kuiper Belt objects*.

Studies via Mission Orbiters

- 🚀 Allows full target imaging.
- 🚀 Allows full target stereo and laser altimetry.
- 🚀 Allows additional instruments to make synergistic datasets, such as temperature, thermal inertia, and mineralogy.
- 🔥 Ideal for global applications and science questions, **likely the most useful for the widest array of crater-based studies.**

Studies via Stationary Landers

- 🚀 Effectively a remote terrestrial geologist + lab.
- 🚀 Crater-wise, best for detailed follow-up work from orbit.
- 🚀 Allows detail stratigraphy examination, mineralogical analysis, and extremely close-up imaging for ground-truthing models based on orbital data.
- 🚀 Could allow with currently TR-6 tech *in situ* radiometric dating, allowing us to better calibrate crater chronology.
- 🔥 Less broad applications than orbiter data, but still incredibly useful, especially if chronology instrumentation is included.

Studies via Mobile Vehicles

- ✈️ Very similar applications to stationary landers.
- ✈️ With the addition of exploring more features/area and doing the same science there (e.g., dating two different terrains).
- ✈️ Aerial studies *en route* to the next target could give synergistic data, such as magnetic field and gravity information.
- 🔥 More crater science than from a stationary lander, if mass/power is not sacrificed for mobility.

Including Funding for Crater Studies in NASA R&A

Existing Planetary Mission Data

-  We have an enormous backlog of important datasets that can be mined for new information via long-standing, or newly developed, or newly-able-to-be-implemented (had been computationally prohibitive) methods.
-  Continued (or boosted) healthy R&A funding is necessary for NASA to realize the **maximum return on investments they already made** to get those data.

Laboratory Experiments

-  Specialized equipment is needed for the high-energy environment of impact crater studies.
-  Lab work provides the only way we can observe the impact process in the real world, start-to-finish, to understand how it works.
-  Is needed to understand equation-of-state for materials so we know how they act under extreme situations.
-  Continued (or boosted) support for existing or proposed labs is needed to understand better how craters form and continue to benefit from investments already made.

Computer Simulations

- 👉 Provide a bridge from lab work to planetary studies to understand how craters on planetary bodies look the way they do.
- 👉 Doing these simulations is hard and requires high-end computing, and/or better methods.
- 👉 If we try to simulate a crater and can't, we are missing or misrepresenting key physics in the process, meaning we do not understand it.

Field Work

- 🚀 Similar to landers on other bodies.
- 🚀 Much of our understanding of material emplacement from impacts comes from terrestrial field work (e.g., drill cores from Meteor Crater).
- 🔥 Still many open questions that require **ground truthing** that only field work can offer. *But*, there is a **funding gap in NASA R&A programs about where terrestrial field work fits.**

Related Studies (Not Always Obvious)

- 👉 Need: Lab work for understanding equations-of-state for different materials.
- 👉 Need: Better (faster) numerical solvers to run more complicated crater simulations.
- 👉 Need: Better AI detection of craters to study some of the remaining questions that require measurements of *millions* of craters.

Summary

- ☄ Impact crater studies are a fundamental part of nearly all solid body exploration across the Solar System.
- ☄ Continued investigations of impact craters should be a key component for all future planetary missions.
- ☄ Continued funding for impact crater studies, including field work, laboratory and computer simulations, and for related fields that could assist crater studies such as artificial intelligence, is critical.