Amor: A Lander Mission to Explore the C-type Triple Near-Earth Asteroid System 2001 SN263. T. Jones[1], P. Lee[1,2,3], J. Bellerose[3,4], E. Fahnestock[5], R. Farquhar[6], M. Gaffey[7], J. Heldmann[3], D. Lawrence[8], M. Nolan[9], T. Prettyman[10], P. Smith[11], P. Thomas[12], J. Veverka[12], G. Benedix[13], R. Elphic[3], R. Gellert[14], A. Hildebrand[15], H. Yano[16], P. Bhavsar[3], J. Chartres[3,4], A. Cox[17], T. Debus[18], R. DeRosee[3], D. Dunham[6], R. Fleischner[18], J. Goldsten[8], J. Horsewood[19], D. Mayer[3], J. McCarthy[17], T. McCarthy[18], G. Mungas[20], D. Osterman[21], H. Sanchez[3], B. Williams[6]. [1]SETI Institute, [2]Mars Institute, [3]NASA Ames Research Center, [4]Carnegie Mellon University, [5]Jet Propulsion Laboratory, [6]KinetX, [7]University of North Dakota, [8]Johns Hopkins University/Applied Physics Lab, [9]NAIC, [10]Planetary Science Institute, [11]University of Arizona, [12]Cornell University, [13]Natural History Museum UK, [14]University of Guelph, [15]University of Alberta, [16]JAXA, [17]Orbital Science Corporation, [18]MDA Information Systems Inc., [19]Spaceflight Solutions, [20]Firestar Technologies Inc., [21]Ball Aerospace.

Summary: Amor is a Discovery-class spacecraft that will rendezvous with, land on, and explore a remarkable triple asteroid system: C-type near-Earth asteroid (NEA) 2001 SN263. C-type asteroids hold clues to the origin of the solar system, the formation of planets, the origins of water and life on Earth, the protection of Earth from impacts, and resources for future human exploration. Yet C-types are dark and difficult to study from Earth, and have only been glimpsed by spacecraft. Amor will take science to a C-type surface.

Fundamental Questions: C-type asteroids are the most common type of asteroids in the inner solar system, and likely the most primitive. On the basis of a good spectral match with carbonaceous chondrite (CC) meteorites (ancient, nearly unaltered meteorites representing pristine relics of solar system formation), C-types are thought to be the parent bodies of CCs. *But are C-types truly linked to CCs?* While C-type asteroids are common (~75% of main belt asteroids are C-types; they are probably a majority among NEAs as well) [1], CCs are rare among recovered meteorites (3%) [2].

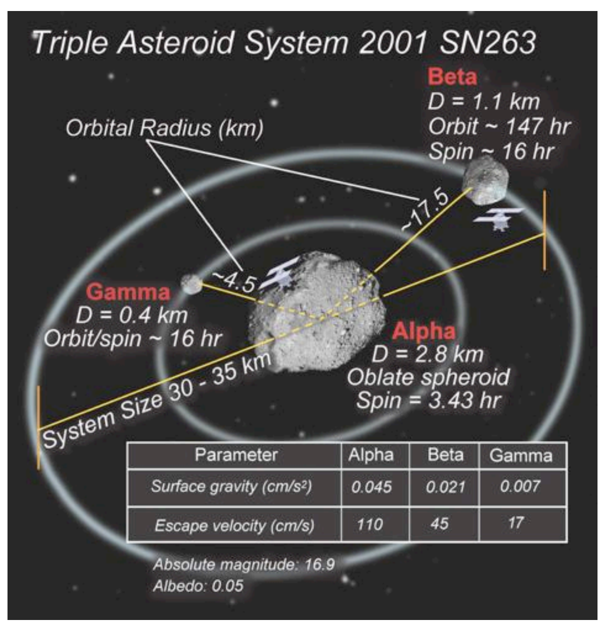
Regardless of any link with CCs, C-type asteroids are a major asteroid type that has yet to be explored in any detail. The only C-type asteroid ever examined by spacecraft is 253 Mathilde. It was only glimpsed during a distant (1,200 km) flyby in 1997 by the NEAR-Shoemaker spacecraft on its way to 433 Eros. Fundamental questions remain unanswered about the nature C-type asteroids: *Are they rich in H_2O? Are they rich in organics? Did C-type impactors deliver much of the water to form Earth's oceans and seed our planet with amino acids and other prebiotic materials?*

Meanwhile, multiple systems and their origin pose an outstanding enigma in asteroid science. Nearly 16% of all known NEOs are multiple asteroids, yet no spacecraft has ever rendezvoused with a multiple asteroid. 243 Ida and its satellite Dactyl were seen by the Galileo spacecraft only by flyby. *How do multiple systems form? What might the interior of a broken up asteroid look like? How do multiple systems evolve?*

C-type NEAs are among the most likely impact threat to Earth. Yet, we know almost nothing about them that would help mitigate an impact risk. *How strong are small C-type NEAs? What is their structure like? How might an impact deflection strategy be planned and implemented?*

NEAs are prominent in NASA's new human exploration plans. Among possible targets, C-types offer the greatest promise in terms of potential resources for future human exploration. *How much H_2O, organics, metals, and regolith do small C-type NEAs truly offer for human exploration?*

The SN263 System: SN263 is a C-type triple asteroid system belonging to the Amor group of NEAs. Amors are named after NEA 1221 Amor. They cross the orbit of Mars and graze the orbit of Earth: i) perihelion 1.017 AU < q< 1.3 AU; ii) semi-major axis, a, > 1 AU. SN263 offers an exceptional opportunity to address all the fundamental questions listed above. It is one of only two triple NEAs identified to date, and the only C-type triple NEA known [3, 4]. The relatively large size and wide spacing of its components (among the widest for NEAs) make it easier and safer to explore than most C-type binary NEAs (Fig.1).



Parameter	Alpha	Beta	Gamma
Surface gravity (cm/s²)	0.045	0.021	0.007
Escape velocity (cm/s)	110	45	17

Fig. 1: Amor's Target: Triple NEA 2001 SN263.

Visible data (0.4-1.0 micron) is not available for SN263. 0.8-4 micron data obtained in 2008 at the NASA IRTF show a featureless spectrum, consistent with a low albedo C-complex object [5]. Thermal emission dominates the spectrum beyond 2.9 microns, consistent with low albedo. The thermal model is consistent with very low thermal inertia.

Science Objectives: The Amor mission's science objectives trace back to NASA strategic goals and objectives, and are organized under three topical areas: 1) Origins; 2) Impact Hazards; and 3) Resources for Human Exploration (Table 1).

Table 1: *Amor* Science Objectives

Origins	
1A	*Test in-situ the long-hypothesized link between C-type asteroids and the primitive CC meteorites.*
1B	*Begin to investigate and characterize in-situ the nature, origin, and evolution of C-type asteroids.*
1C	*Investigate the hypothesis that C-type asteroids are H_2O-rich, particularly small ones.*
2	*Investigate in-situ the origin and evolution of multiple asteroids. Test the asteroid break-up hypothesis.*
3	*Investigate the origin, distribution, and evolution of solar system volatiles and organic and prebiotic materials in the context of a primitive asteroid.*
Impact Hazards	
4A	*Characterize the geology and physical properties of small (0.4 km, 1 km, and 2.8 km) C-type objects and the dynamical properties of a multiple asteroid, to understand the impact hazard posed to Earth by common potentially hazardous asteroids (PHAs), and inform future mitigation strategies.*
Resources for Human Exploration	
4B	*Determine the abundance, distribution, and accessibility of H, H2O, organics, metals, regolith, and other potential resources on C-type asteroids, for human exploration.*

Science Payload: To address the above objectives, Amor will carry three instruments, and also conduct radio science (Table 2).

Table 2: *Amor* Instruments

NEOCam (Near-Earth Object Camera) *Color remote sensing imager and mapper to investigate the dynamics, shape, and surface geology of the SN263 system and its components, search for any additional satellites and debris, and select landing sites.*
NEONS (Near-Earth Object Nuclear Spectrometer) *Combination Neutron Spectrometer (NS) and Gamma Ray Spectrometer (GRS) for elemental abundance and ratios measurements and mapping during close approaches and once landed.*
CHAMP (Camera Hand lens And Microscope Probe) *Variable focal length color imager capable of focusing from infinity down to 3 microns per pixel with controlled LED lighting. CHAMP is mounted on the end of a robotic arm.*

Mission Profile: Amor will launch on an Atlas 401-class rocket in Jan 2017 on a ΔVEGA trajectory, swing by the Earth in Feb 2019, fly by several asteroids including 12 Victoria, and rendezvous with 2001 SN263 in Nov 2021. Over the following weeks, Amor will map the SN263 system in detail, look for any additional satellites and debris, select landing sites, and land on two C-type components in the system, probably Alpha and Beta (Fig.1). High-precision landing will be enabled through the use of a landing lidar system. Surface stays on each component will last about 1 week. At each landing site, detailed elemental composition measurements will be made, along with high-resolution color imaging of surface features at macroscopic and microscopic scales (color microscopy at 20 spots per landing site). Workspace cameras will assist in robotic arm placement of CHAMP (Fig. 2).

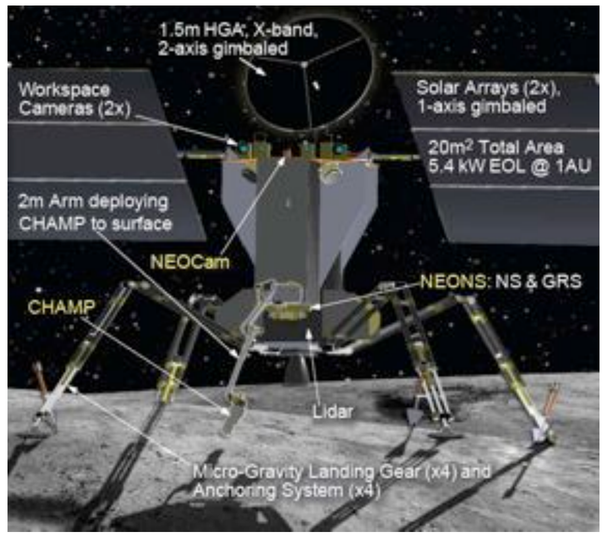


Fig.2: The Amor Lander, with its micro-gravity landing gear and anchoring system, three science instruments (yellow lettering), and 2m arm. The spacecraft will be built by Orbital Sciences Corp.

Mission of Many Firsts: Amor will be the first mission to:

- *Soft-land on an asteroid for detailed, in-situ examination of surface materials in context.*
- *Explore a C-type asteroid in detail.*
- *Explore a multiple asteroid and land on several bodies.*
- *Investigate small C-type NEAs, the most likely impact threat to Earth.*
- *Inventory in-situ resources on C-type NEAs.*

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Note: At the time of this abstract's submission, Amor was a Discovery mission proposal submitted to NASA and under review.