

The Asteroid Criticality Index: a tool for the future exploration of Solar System small bodies

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Abstract. When planning space exploration mission, the large amount of data available about Solar System small bodies gives us the opportunity to choose among a large variety of targets. However, determining which one realizes the best costs-to-benefits ratio is still challenging. Here we introduce the concept of Asteroid Criticality Index, i.e. an asteroid ranking that evaluates how important an object is to be studied by means of a space mission, that could help in the planning and implementation of future small-body missions.

Keywords: Asteroids · Small Bodies · Mission Concept.

1 Motivations

Today, more than one million small Solar System's objects are known, and digging into the large amount of available data is not always an easy task. For this reason, the need for ranking and prioritization to help navigating into asteroid databases has grown during the last decade. Several asteroid rankings have been developed so far, each of them having a different purpose and addressed to different kind of audiences, see e.g. [1], [2], [3].

Here we present the concept of Asteroid Criticality Index (ACI), an asteroid ranking that aims to identify suitable targets for future small-body exploration mission. The tool has been developed to be flexible and customizable according to the needs of the user, and it is publicly available through a web interface.

2 The Asteroid Criticality Index

To evaluate the relevance of a small body for a space mission, the ACI takes into account: 1) the scientific knowledge returned; 2) the impact threat; 3) the value of in-situ resources; 4) the accessibility of the object. Due to this general definition, the index is addressed to a wide audience, including the planetary science community, public and private space companies, and policy makers. In

addition, it could be used as a tool to ease the communication and support the endorsement of the public opinion. The ACI is designed for the population of near-Earth and main-belt asteroids, main-belt comets, Jupiter-family comets, and Jupiter Trojans, and it is defined as

$$I_{\text{crit}} = w_1 I_{\text{sci}} + w_2 I_{\text{imp}} + w_3 I_{\text{res}} + w_4 I_{\text{acc}}. \quad (1)$$

The terms I_{sci} , I_{imp} , I_{res} , I_{acc} are functions assuming values between 0 and 1, and measuring the scientific return, the impact threat, the value of the resources, and the accessibility of a given object, respectively. The values w_i , $i = 1, 2, 3, 4$ are positive weights such that their sum is unitary.

Scientific relevance The exploration of asteroids and comets could reveal answers on the origin of the Solar System, and on how life on Earth started. The term I_{sci} evaluates the importance of a small body to understand: 1) the formation process and the initial conditions of the Solar System; 2) the evolution of the Solar System; 3) the processes in an active Solar System; 4) the delivery of elements to sustain life.

Impact threat Near-Earth asteroids pose a threat because they may impact the Earth, causing significant damage [4]. The term I_{imp} evaluates the relevance of a given asteroid for planetary defense purposes, taking into account its probability of impact with the Earth.

Value of resources Small bodies are considered to be reservoirs of raw materials such as semiconductors, volatiles and water, and rare platinum group metals. These materials could be either processed in-situ or be collected and brought back to Earth. The term I_{res} estimates the value of in-situ resources, according to the known information about size and composition.

Accessibility The most relevant parameter indicating the feasibility of a space mission, in terms of costs, is the ΔV needed to reach the target. The term I_{acc} evaluates the accessibility of a small body through a ΔV estimation of a rendezvous transfer orbit [5].

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