

Robotic Manipulation and Capture in Space: A Survey

1 **Evangelos Papadopoulos^{1*}, Farhad Aghili², Ou Ma³, Roberto Lampariello⁴**

2 ¹Control Systems Lab, School of Mechanical Engineering, National Technical University of Athens,
3 Athens, Greece

4 ²Space Exploration, Canadian Space Agency (CSA), Montreal, Quebec, Canada

5 ³Intelligent Robotics and Autonomous Systems Lab, College of Engineering and Applied Science,
6 University of Cincinnati, Cincinnati, Ohio, USA

7 ⁴Institute of Robotics and Mechatronics, German Aerospace Center (DLR), Germany

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9 *** Correspondence:**

10 Corresponding Author

11 egpapado@central.ntua.gr

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16 **Abstract**

17 Space exploration and exploitation will depend on the development of on-orbit robotic capabilities
18 for tasks such as servicing of satellites, removing of orbital debris, or construction and maintenance
19 of orbital assets. Manipulation and capture of objects on-orbit are key enablers for these capabilities.
20 This survey addresses fundamental aspects of manipulation and capture, such as the dynamics of
21 space manipulator systems (SMS), i.e., satellites equipped with manipulators, the contact dynamics
22 between manipulator grippers and targets, and the methods for identifying properties of SMSs and
23 their targets. Also, it presents recent work in the area of sensing of pose and system states, of motion
24 planning for capturing a target, and of feedback control methods for SMS during motion or
25 interaction tasks. Finally, the paper reviews major ground testing testbeds for capture operations, and
26 a number of notable missions and technologies developed for the capture of targets on-orbit.

27 **1 Introduction**

28 Space exploration and exploitation depend on tasks such as inspecting, refueling, upgrading,
29 repairing, or rescuing satellites, removing of orbital debris, and construction and maintenance of
30 large orbital assets and infrastructures. Until now, all notable servicing tasks have been performed at
31 Low Earth Orbit (LEO) by astronaut Extravehicular Activities (EVAs). However, EVAs are by
32 nature risky operations requiring careful planning and preparation. Unfortunately, this increases
33 mission costs and turn-around time drastically, making servicing missions too costly, of prolonged
34 development, or even unfeasible. For critical space assets located in Geostationary Earth Orbits
35 (GEO) or other high-altitude orbits, EVA is not even an option in the foreseeable future.

36 To execute on-orbit tasks being inaccessible to, or too dangerous for humans, robotic on-orbit
37 servicing (OOS) can be employed, with tasks to be performed by *space manipulator systems* (SMSs),
38 also called *chasers* or *servicers* in the literature. An SMS consists of a satellite base equipped with