

CLAIMS

1. An on-orbit servicing spacecraft (1) comprising:
- an engagement system (4) to engage a space vehicle or object (5) to be serviced or
5 tugged, so as to form a space system (6); and
 - an electronic reaction control system (7) to cause the spacecraft (1) to rotate about roll, yaw, and pitch axes to control attitude and displacement of the spacecraft (1) along given trajectories to cause the spacecraft (1) to carry out given manoeuvres;
- the electronic reaction control system (7) comprises:
- 10 - a sensory system (8) to allow physical quantities to be directly sensed or indirectly computed based on sensed physical quantities comprising one or more of position, attitude, angular rates, available fuel, geometrical features, and on-board system state;
 - attitude control thrusters (9) mounted so as to allow their positions and orientations to be adjustable; and
 - 15 - an attitude control computer (10) in communication with the sensory system (8) and the attitude control thrusters (9) and programmed to receive data from the sensory system (8) and to control, based on the received data, positions, orientations, and operating states of the attitude control thrusters (9) so as to control attitude and position of the spacecraft (1);
- the attitude control computer (10) is programmed to cause the spacecraft (1) to carry
20 out a given mission comprising an engagement step, in which the engagement system (4) and the attitude control thrusters (9) are controlled by the attitude control computer (10) to engage a space vehicle or object (5) to be serviced or tugged, and one or more operating steps, in each of which the attitude control thrusters (9) are controlled by the attitude control computer (10) to meet one or more requirements established for the operating step;
- 25 each operating step may comprise at least one stabilisation sub-step (FS) during which the attitude of the space system (6) is stabilised in accordance with the requirements of the operating step and with a given optimisation criterion;
- characterised in that** each stabilisation sub-step (FS) is followed by a steady operating sub-step (FR), which starts when the stabilisation sub-step (FS) of the attitude
30 of the space system (6) ends; and
- in that** in each operating step the attitude control computer (10) is further programmed to optimise a configuration of the attitude control thrusters (9) in accordance with the requirements of the operating step by implementing an iterative process of optimisation of the configuration of the attitude control thrusters (9) comprising:

1. Operation 1 comprising:
 - 1.1 acquiring/updating the requirements of the operating step and the optimisation criterion;
 - 1.2 acquiring/updating the current state of the space system (6) defined by position, orientation, and angular speeds of the space system (6) in a reference system of the space system (6);
 - 1.3 determining position and orientation of the engaged space vehicle or object (5) relative to the spacecraft (1) so as to allow the geometrical configuration of the space system (6) to be determined; and
 - 1.4 determining current positions and orientations of the attitude control thrusters (9);
2. Operation 2 comprising:

stabilising the attitude of the space system (6) in compliance with the requirements of the operating step and with the optimisation criterion, based on the current state and the geometrical configuration of the space system (6) and on the current positions and orientations of the attitude control thrusters (9) determined in step 1.4;
3. Operation 3 comprising:
 - 3.1 determining attitude control forces and torques acting on the space system (6) during a sufficiently extended sampling period of the steady operating step (FR); and
 - 3.2 determining admissible position and orientation domains of the attitude control thrusters (9) and availability of the attitude control thrusters (9);
4. Operation 4 comprising:

optimising positions and orientations of the available attitude control thrusters (9), based on the optimisation criterion and considering the positions and orientations of the attitude control thrusters (9) as system variables that may vary within the associated admissible domains determined in step 3.2;
5. Operation 5 comprising:

modifying positions and orientations of the attitude control thrusters (9) so as to cause the attitude control thrusters (9) to assume the optimised positions and orientations computed in step 4.1.
2. The on-orbit servicing spacecraft (1) of claim 1, wherein the attitude control computer (10) is further programmed to:
 - when Operation 3 has been completed, checking (150) occurrence of a first operating condition defined by execution of Operation 3 having, or failing to have, resulted in a variation of the operating scenario of the space system (6) defined by the set of attitude control forces and torques applied to the space system (6) and/or by the

availability, or lack thereof, of one or more attitude control thrusters (9) compared to the operating scenario prior to execution of Operation 3 in the iterative process of optimisation of the configuration of the attitude control thrusters (9);

- if the first operating condition is determined to have occurred, executing Operation 4 (130); and
- if the first operating condition is determined not to have occurred, repeating Operation 1 after a given time period (160) has elapsed.

3. The on-orbit servicing spacecraft (1) of claim 1 or 2, wherein the attitude control computer (10) is further configured to:

- when Operation 4 has been completed, checking (170) occurrence of a second operating condition defined by execution of Operation 4 having, or failing to have, resulted in an improvement, determined based on the optimisation criterion, compared to the previous executions of Operations 4 in the iterative process of optimisation of the configuration of the attitude control thrusters (9);
- if the second operating condition is determined to have occurred, executing Operation 5 (140); and
- if the second operating condition is determined not to have occurred, repeating Operation 1 after a given time period (160) has elapsed.

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4. The on-orbit servicing spacecraft (1) of any one of the preceding claims, wherein the attitude control computer (10) is further programmed to implement one or more of the stabilisation sub-step (FS), determination of an update need as per step 1.1 in Operation 1, Operation 2, and step 3.2 in Operation 3 by means of either one and the same or different neural networks previously trained on the ground.

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5. The on-orbit servicing spacecraft (1) of any one of the preceding claims, wherein the attitude control computer (10) is further programmed to determine position and orientation of the space vehicle or object (5) to be serviced or tugged relative to the spacecraft (1) and the geometrical configuration of the space system (6) as per step 1.3 in Operation 1 based on data outputted by the sensory system (8).

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6. The on-orbit servicing spacecraft (1) of any one of the preceding claims, wherein the attitude control computer (10) is further programmed to execute Operation 3 when the space system (6) meets the requirements of the operating step and the optimisation criterion.

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7. The on-orbit servicing spacecraft (1) of any one of the preceding claims, wherein the attitude control computer (10) is further programmed to execute step 3.1 in Operation 3 by extracting a subset of attitude control forces and torques applied to the space system (6) and representative of attitude control forces and torques applied to the space system (6) during control steps that have taken place during the steady operating step (FR).

8. The on-orbit servicing spacecraft (1) of claim 7, wherein the attitude control computer (10) is further programmed to extract a subset of attitude control forces and torques applied to the space system (6) and comprising attitude control forces and torques applied to the space system (6) during critical attitude control steps that have taken place during the steady operating sub-step (FR) and/or attitude control forces and torques more frequently applied on the space system (6) during the steady operating sub-step (FR).

9. The on-orbit servicing spacecraft (1) of any one of the preceding claims, wherein the electronic reaction control system (7) further comprises an electronically-controllable movement system (11) operable to move the attitude control thrusters (9) and comprising:

- an electronically-controllable orientation structure (12) designed to support one or different attitude control thrusters (9) so as to allow them to rotate about at least two orthogonal rotation axes (A, B) in response to electrical commands from the attitude control computer (10), so as to allow orientation of the attitude control thrusters (9) to be adjustable;
- an electronically-controllable positioning structure (13) designed to support one or different orientation structures (12) so as to allow them to translate along a displacement direction in response to electrical commands from the attitude control computer (10), so as to allow position of the orientation structures (12) to be adjustable; and
- for each positioning structure (13), an electronically-controllable deployment structure (14) designed to connect the positioning structure (13) to the spacecraft (1) and to assume, in response to electrical commands from the attitude control computer (10), an undeployed configuration in which the positioning structure (13) is close to the spacecraft (1), and a deployed configuration, in which the positioning structure (13) is moved away from the spacecraft (1) and brought in a position close to the space vehicle or object (5) to be serviced or tugged.

10. A software loadable in the attitude control computer (10) of the electronic reaction control system (7) of the on-orbit servicing spacecraft (1) of any one of the preceding claims and designed to cause, when executed, the attitude control computer (10) to become configured as claimed in any one of the preceding claims.