# ANNEX A

## MILIARIUM AD ASTRA GRAND CHALLENGES

A1.1 The Miliarium Ad Astra Grand Challenges are singular events in the history of spaceflight and/or demonstrations of significant technical capabilities which are critical to spaceflight advancement. The following challenges are recognized.

A2.1 THE SPACECRAFT REUSABILITY CHALLENGE

A2.2 **Objective**: This challenge recognizes the first orbital flight of a fully reusable human rated spacecraft.

A2.2.1 The ability to reuse orbital class spacecraft is a key enabling capability to allow routine and economical access to space.

A2.3 **Period of Performance**:

A2.3.1 Mission initiation is the launch of the spacecraft.

A2.3.2 The Spacecraft Reusability Challenge is achieved when a crewed human rated spacecraft makes a safe landing after a successful launch and orbital flight and post-flight inspection verifies that each major component of the spacecraft can be reused for a subsequent mission with only minor refurbishment.

A2.3.3 The mission is complete when all major components have landed or been recovered.

A2.4 **Critical Elements**:

A2.4.1 The spacecraft must be a crewed, human rated spacecraft designed for and flown on a mission profile the allows recovery and reuse of all major components.

A2.4.2 The spacecraft must successfully launch and achieve orbit.

A2.4.3 Each major component makes a successful landing and is recovered.

A2.4.4 Post-flight inspection and analysis shows that each major spacecraft component is spaceworthy and capable of a second flight with only minor maintenance and refurbishment activity.

A2.5 **Challenge Rules**:

A2.5.1 The spacecraft must be crewed during the challenge flight.

A2.5.2 The spacecraft or spacecraft component carrying the crew must achieve orbit and complete a minimum of 20 orbits before initiating a reentry.

A2.5.3 Each component of the spacecraft must make a safe landing and be recovered.

A2.5.4 All members of the mission crew must survive the flight. If a crewmember dies within 24 hours of a condition caused by or exasperated by the flight, the challenge attempt is invalid.

A2.5.5 A post-fight inspection must assess the condition of each major component. Each component must be capable of a second flight within 90 days of mission completion. In making this determination, minor maintenance actions and refurbishment are allowable to return a component to flight ready status.

A2.5.6 Components which are not repairable to flight ready status may be replaced, however, a minimum of 90% of the original spacecraft by weight must be flight ready and capable of a second flight to be considered reuseable. The 90% metric is determined using the original spacecraft dry weight.

A2.6 **Data and Measurements**:

A2.6.1 Dry weight of spacecraft in the takeoff configuration not including propellants, consumables and crew. Weight may be determined directly through weighing or by design and engineering information.

A2.6.2 Documentation of time and place of mission initiation (Launch).

A2.6.3 Documentation of time and orbital parameters of crewed spacecraft when established in orbit.

A2.6.4 Telemetry data documenting crewed spacecraft completion of 20 orbits prior to deorbit and reentry initiation.

A2.6.5 Documentation of time and orbital parameters of initiation of crewed spacecraft deorbit and reentry initiation.

A2.6.6 Documentation of time and place of landing of each spacecraft component.

A2.6.7 Data indicating the status of each spacecraft component following the flight and the post-flight inspection. Data must indicate the capability of the spacecraft to perform another flight within 90 days following mission completion.

A2.6.8 Documentation of maintenance and refurbishment tasks and component replacements required for spacecraft components to be spaceworthy for a second flight. documentation must show that a minimum of 90% of the original spacecraft (by dry weight) would be present for a second flight.

A3.1 <u>THE ORBITAL REFUELING CHALLENGE</u>

A3.2 **Objective**: This challenge recognizes the first large mass spacecraft-to-spacecraft propellant transfer.

A3.2.1 On orbit refueling is a key enabling technology to extend missions and spacecraft mobility. Orbital refueling may also facilitate new spacecraft designs and mission profiles including transport class spacecraft constructed in orbit, orbital propellant

storage and refueling depots and the ability to use in situ fuel produced on other celestial bodies.

A3.3 **Period of Performance**:

A3.3.1 Mission initiation is the launch of the receiver spacecraft or the tanker spacecraft whichever is earlier.

A3.3.2 The Orbital Refueling Challenge is achieved when 25,000 kg of cryogenic spacecraft propellant (fuel, oxidizer or both) is transferred from a tanker spacecraft to a receiver spacecraft.

A3.3.3 The mission is complete when the transfer is complete, and the spacecraft have undocked or otherwise disconnected and moved to a safe separation distance.

A3.4 **Critical Elements**:

A3.4.1 The receiver and tanker spacecraft must both launch successfully, achieve orbit and rendezvous.

A3.4.2 The receiver and tanker spacecraft must maneuver and dock or otherwise conduct station keeping in close proximity and connect propellant transfer equipment as required by the refueling operation.

A3.4.3 A minimum of 25,000 kg of propellant must be transferred from the tanker spacecraft to the receiver spacecraft. A portion of the transfer must be cryogenic fuel or oxidizer.

A3.4.4 When the transfer is complete, the spacecraft undock or otherwise disconnect the transfer equipment and move to a safe separation distance.

A3.5 **Challenge Rules**:

A3.5.1 The propellant transfer must take place between one receiver spacecraft and one or more tanker spacecraft.

A3.5.2 The transfer must include a minimum of 2,500 kg of cryogenic propellant, either fuel or oxidizer, or both.

A3.6 **Data and Measurements**:

A3.6.1 Documentation of time and place of launch of the receiver spacecraft and each tanker spacecraft used for the challenge.

A3.6.2 Documentation of the time and orbital parameters when the receiver and tanker spacecraft dock or connect propellant transfer equipment.

A3.6.3 Documentation of the time and orbital parameters when the final transfer is complete.

A3.6.4 Documentation of the type and mass of total propellant mass transferred and the type and mass of cryogenic propellant. If more than one tanker spacecraft is used each transfer should be documented separately.

A4.1 THE ORBITAL DEBRIS MITIGATION CHALLENGE

A4.2 **Objective**: This challenge recognizes the first third party active removal of orbital debris greater than 1000 kg.

A4.2.1 Although space is vast, the low earth orbit (LEO) region (less than 2000 km orbital altitude) is becoming increasingly crowded. The growing number of active satellites and the amount of space debris (old or non-operational satellites, expended rocket bodies, and debris from space object collisions) increase the probability of collisions which can result in more debris and increased hazards to satellites and crewed spacecraft. Current best practice and some national regulations require satellites to deorbit or be moved to a "graveyard" orbit for safe storage at the end of life. However, older satellites, malfunctioning satellites and other objects may not have an integral deorbit capability. Active removal by a third-party operator is a key capability to address this need and protect the space environment and the safety of crewed and uncrewed space operations.

A4.3 **Period of Performance**:

A4.3.1 Mission initiation is either, 1) the launch of the debris removal spacecraft (DR spacecraft) or, 2) first movement of a pre-positioned DR spacecraft from a parking orbit or on-orbit depot to rendezvous with the target spacecraft.

A4.3.2 The Orbital Debris Mitigation Challenge is achieved when the target spacecraft either, 1) deorbits, and burns up during reentry or reenters and impacts in a safe location or, 2) is moved to a stable graveyard orbit for safe storage.

A4.3.3 The mission is complete when the Orbital Debris Mitigation Challenge is achieved.

A4.4 **Critical Elements**:

A4.4.1 The DR spacecraft launches or a prepositioned DR spacecraft initiates orbital maneuvers to rendezvous with the target spacecraft.

A4.4.2 The DR spacecraft identifies, rendezvous with, and initiates removal of the target spacecraft.

A4.4.3 The target spacecraft deorbits and reenters or is established in a stable graveyard orbit.

A4.5 **Challenge Rules**:

A4.5.1 The target spacecraft must be a non-cooperating target. A "non-cooperating target" means that the target spacecraft cannot make attitude or orbital maneuvers or make configuration changes (including electronic equipment) to facilitate rendezvous and the debris removal operations.

A4.5.2 The target spacecraft must have a mass of 1000 kg or greater and must be in a LEO orbit with a minimum perigee of 800 km.

A4.5.3 For target spacecraft which are expected to survive reentry and impact Earth, the target area must be declared in advance, must meet the reentry safety requirements of the country with oversight of the DR spacecraft operator, and the actual impact location must be within 500 km of the declared target.

A4.5.4 For target spacecraft which are moved to a safe storage graveyard orbit, the orbital parameters of the final orbit must be declared in advance and achieved within 5% of the declared values.

A4.5.5 The challenge elements must be completed within 30 days of mission initiation.

A4.6 **Data and Measurements**:

A4.6.1 Data or documentation indicating the mass of the target spacecraft in the on-orbit, "as-is" configuration.

A4.6.2 Documentation of orbital parameters of the target spacecraft prior to mission initiation.

A4.6.3 Documentation of time and place of mission initiation (launch or initiation of orbital maneuvering for rendezvous).

A4.6.4 Data indicating time and place of DR spacecraft rendezvous with target spacecraft.

A4.6.5 Data indicating time and place of either target spacecraft deorbit maneuver, or movement towards graveyard orbit.

A4.6.6 Documentation of time and place of target spacecraft impact or time and orbital parameters of target spacecraft when established in graveyard orbit.

A5.1 <u>THE LUNAR SOUTH POLE LANDING CHALLENGE</u>

A5.2 **Objective**: This challenge recognizes the first human landing at and exploration of the lunar south polar region.

A5.2.1 The lunar south pole region is a compelling location for exploration missions and suitable for lunar outposts. The permanently shadowed craters on the Moon contain water ice and other minerals, which will be vital resources for future explorers. The mountain peaks near the pole are illuminated for large periods of time and could be used to provide solar energy to an outpost.

A5.3 **Period of Performance**:

A5.3.1 Mission initiation is the launch of the spacecraft carrying the mission crew.

A5.3.2 The Lunar South Pole Landing Challenge is achieved when the descent and landing vehicle makes a successful landing on lunar surface, the surface expedition crewmembers have walked on the Moon and conducted extravehicular exploration activities, and the original mission crew have returned to and safely landed on the Earth.

A5.3.3 The mission is complete when the crew makes a successful return to and landing on Earth.

A5.4 **Critical Elements**:

A5.4.1 The descent and landing vehicle must land in the lunar south polar region defined as the area between 80 degrees and 90 degrees south latitude on the Moon.

A5.4.2 The surface expedition crewmembers conduct extravehicular exploration activities on the Moon's surface.

A5.4.3 The mission crew returns to and safely lands on the Earth.

A5.5 **Challenge Rules**:

A5.5.1 The descent and landing vehicle must make a successful landing between 80 degrees and 90 degrees south latitude on the Moon.

A5.5.2 The surface expedition crewmembers must exit the descent and landing vehicle and conduct extravehicular exploratory activities. Exploratory activities include taking measurements, collecting samples, and operating equipment.

A5.5.3 The surface expedition crew must make a successful ascent from the lunar surface.

A5.5.4 The mission crew must return to and safely land on the Earth.

A5.5.5 The surface expedition crewmembers will be identified, but each member of the mission crew will be recognized for the award of the FAI Gold Space Medal.

A5.6 **Data and Measurements**:

A5.6.1 Data indicating the time and place of mission initiation (spacecraft launch).

A5.6.2 Spacecraft telemetry data showing initiation of descent to the lunar surface.

A5.6.3 Spacecraft telemetry indicating time and place (latitude and longitude in lunar coordinate system) of the descent and landing vehicle touchdown on the Moon.

A5.6.4 Video, mission logs or other data documenting surface expedition crewmember extravehicular exploration activities on the lunar surface.

A5.6.5 Spacecraft telemetry data showing initiation of ascent from the lunar surface.

A5.6.6 Spacecraft telemetry or other data indicating time and place of mission crew landing on Earth.

A6.1 <u>THE MARS LANDING CHALLENGE</u>

A6.2 **Objective**: This challenge recognizes the first human landing and presence on Mars.

A6.3 **Period of Performance**:

A6.3.1 Mission initiation is the initial application of thrust to leave Earth near space and proceed to Mars.

A6.3.2 The Mars Landing Challenge is achieved when the descent and landing vehicle makes a successful landing on Mars and a crewmember takes the first steps on the surface of Mars.

A6.3.3 The mission is complete when the crew or portion thereof makes a successful return and landing on Earth.

A6.4 **Critical Elements**:

A6.4.1 The crew of the descent and landing vehicle must survive the landing and remain alive for 24 hours following the first step.

A6.4.2 A crewmember takes the first step onto the surface of Mars.

A6.5 **Challenge Rules**:

A6.5.1 The time of the first step on Mars will be recorded as local Earth time in UTC corrected for communications signal transit time from Mars.

A6.5.2 The person making the first step on Mars will be identified, but each member of the crew participating in the surface exploration of Mars will be recognized for the award of the FAI Gold Space Medal.

A6.6 **Data and Measurements**:

A6.6.1 Spacecraft telemetry data indicating time and place of mission initiation and initial trajectory for transit to Mars.

A6.6.2 Spacecraft telemetry data showing Mars orbital insertion.

A6.6.3 Spacecraft telemetry data showing initiation of descent.

A6.6.4 Spacecraft telemetry and video documentation of descent and landing vehicle touchdown on Mars.

A6.6.5 Video documentation of first step onto surface of Mars.

A6.6.6 Video, personal medical telemetry or other data indicating crew survival for 24 hours following the first step.

A6.6.7 Mission logs, video or other data identifying each crewmember who participates in surface exploration activities.