

Review

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Review

Astronaut Selection: Implications for the New Era of Spaceflight

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Abstract

The rapid expansion of commercial human spaceflight is forcing a re-examination of how we decide who is “fit to fly” in space. For six decades, astronaut selection has been dominated by national space agencies using stringent, mission-driven criteria grounded in risk minimisation and long-duration operational demands. Contemporary standards such as NASA-STD-3001 and agency-specific medical regulations embed a philosophy in which astronauts are rare, heavily trained national assets expected to tolerate extreme environments with minimal performance degradation. In contrast, commercial operators aim to fly large numbers of spaceflight participants (SFPs) with highly heterogeneous medical and psychological profiles, under a US regulatory regime that emphasises informed consent and currently imposes very limited prescriptive health requirements on passengers. This article reviews the evolution and structure of traditional astronaut selection, outlines emerging approaches to screening and certifying commercial spaceflight customers, and explores the conceptual and practical gap between “selection” and “screening”. Drawing on agency standards, psychological selection research, and recent proposals for commercial medical guidelines, it proposes a risk-informed, mission-specific framework that adapts lessons from government astronaut corps to the needs of commercial spaceflight. We argue that future practice must balance inclusion and market growth with transparent, evidence-based risk management, supported by systematic data collection across government and commercial flights.

Keywords: astronaut selection; commercial human spaceflight; spaceflight participant; medical screening; psychological selection; NASA-STD-3001; safety regulation

1. Introduction

For most of the Space Age, human spaceflight was the exclusive domain of government programmes. Astronauts were selected as elite, highly screened professionals whose role was to execute technically demanding missions in unforgiving environments with very limited rescue options [1]. Early selection programmes in the United States and Soviet Union focused on military test pilots with exceptional physical robustness and psychological resilience, reflecting Cold War priorities and the experimental nature of space systems [2]. Over time, astronaut corps diversified to include scientists, physicians, and engineers, but the underlying philosophy of stringent, mission-driven selection has remained [3].

In parallel, agency-level standards have become increasingly codified. NASA's Space Flight Human System Standards (NASA-STD-3001) articulate comprehensive requirements for crew health, performance, training, and medical care, alongside detailed vehicle and environmental design criteria [1,4]. ESA and other agencies have developed multi-phase psychological and medical selection processes that extend over many weeks and integrate cognitive testing, personality assessment, medical imaging, and high-fidelity operational simulations [3,5,6].

The emergence of commercial human spaceflight (encompassing suborbital tourism, commercial orbital flights, and planned commercial space stations) introduces a new paradigm. Operators such as Blue Origin, Virgin Galactic, and SpaceX seek to fly large numbers of customers, many of whom are older and have stable chronic conditions, for short-duration (hours/days) and in due course longer missions (days/weeks) [7,8]. The centre of gravity for human spaceflight globally remains the USA. The current US regulatory framework for commercial spaceflight participants emphasises informed consent, with limited prescriptive medical standards for passengers and no single, universally accepted set of industry guidelines for medical screening [8–11].

This creates a tension: how can the proven benefits of rigorous astronaut selection be translated into a commercial environment that must not “select away” the majority of its potential customers? This paper examines that conflict by (i) summarising traditional astronaut selection objectives and methods; (ii) describing the emerging landscape of commercial spaceflight participant screening; and (iii) proposing a risk-stratified framework that reframes “selection” as “screening and certification” for diverse participant populations.

2. Traditional Astronaut Selection: Objectives and Architecture

Government astronaut selection has always been intimately linked to mission risk and national prestige. Early US programmes (Mercury, Gemini, Apollo) recruited almost exclusively from high-performance military aviators [2,12]. Later, Shuttle and ISS eras introduced mission specialists and “payload specialists”, but all astronauts were still subject to highly restrictive medical and psychological criteria and long training pipelines.

Today, NASA, ESA, JAXA and other agencies maintain structured, multi-stage selection processes. ESA’s recent campaigns, for example, involve an initial paper and eligibility screen, followed by cognitive testing, group exercises, technical interviews, and extensive psychological and medical evaluations conducted over a number of months [3,6]. These processes are designed not just to identify medically robust individuals, but to select people able to perform reliably under isolated, heavy workload, extreme-environment missions, with higher-than-normal risks, that last six months or longer [5,13].

Medical selection standards for career astronauts are fundamentally mission-driven and risk-averse. NASA-STD-3001 (Volume 1) defines health and medical care standards to minimise the probability that medical events compromise mission objectives or crew safety and is complemented by specific astronaut medical standards and recertification requirements [1,14]. ESA uses comparable criteria, emphasising cardiovascular fitness, absence of serious chronic disease, normal imaging and laboratory findings, and the ability to tolerate altered gravity, confinement, and high-stress circumstances [2,3].

Key features of traditional medical selection include:

- Low tolerance for risk of acute incapacitation (e.g., stringent cardiac evaluations; exclusion or strict control of epilepsy, insulin-dependent diabetes, and significant pulmonary disease) [1,14].
- Screening for conditions that may be exacerbated by spaceflight (e.g., ophthalmic pathologies in the context of Spaceflight Associated Neuro-ocular Syndrome; renal stone risk; susceptibility to decompression sickness) [15–18].
- Emphasis on long-term health and cumulative exposure, given repeated missions and extended stays in microgravity environments [1,13].

The ESA “Parastronaut Feasibility Project” marks a notable evolution, exploring how astronauts with certain physical disabilities might be accommodated without compromising safety, using a rigorous, data-driven approach to redefining medical disqualifiers [19,20].

Psychological selection is equally central. The leading space agencies incorporate batteries of cognitive tests (e.g. spatial reasoning, memory, attention, multi-tasking) and personality assessments to identify candidates who can function effectively in small teams, under time pressure, and in confinement [5,6,21]. Desired profiles emphasise emotional stability, low aggression, cooperative mindsets, and the ability to manage stress and ambiguity [5,21].

Empirical work in European cohorts shows that cognitive aptitudes relevant to mission tasks such as spatial orientation, psychomotor coordination and multiple-task capacity are predictive of performance and are therefore emphasised in selection batteries [5,6]. High-fidelity simulations and analogue environments (e.g. isolation missions, underwater training) are used not only for training but also as extended selection tools, providing insight into interpersonal dynamics and operational behaviour [2,13].

Underlying these processes is a consistent risk philosophy:

- Small numbers, high investment: Astronaut corps are small, and each individual represents a major investment in training and mission planning [1].
- High consequence of failure: In-flight incapacitation, serious behavioural issues, or poor performance can jeopardise multi-billion-dollar missions and international partnerships [1,2].
- Long-duration, high-demand missions: ISS and exploration missions demand sustained performance under physiological and psychological stressors that far exceed those of brief commercial suborbital experiences [13,17].

As a result, traditional astronaut selection is exclusive by design. The majority of otherwise healthy and capable applicants are rejected on medical, psychological, or operational grounds in order to minimise rare but high-impact failure modes [2,3].

3. The Emerging Commercial Human Spaceflight Landscape

Commercial human spaceflight is broadening both mission profiles and participant populations. Suborbital vehicles (e.g. New Shepard, SpaceShipTwo) provide several minutes of microgravity and expose participants to short, high-magnitude G-loads and G-transitions, and microgravity [8]. Orbital missions using vehicles such as Crew Dragon and Starliner can range from a few days to multi-week private missions and will likely feed into commercial space station operations [7], exposing spaceflight participants to extended microgravity and other stressors.

Crucially, most spaceflight participants are not career astronauts. They may be older, have well-managed chronic conditions (e.g. hypertension, prior coronary interventions, diabetes), and have very heterogeneous levels of physical fitness and psychological readiness. Case reports of spaceflight participants on ISS already illustrate the challenge of accommodating individuals with significant pre-existing conditions through intensive pre-flight evaluation and mitigation strategies [22].

In the United States, the Federal Aviation Administration's Office of Commercial Space Transportation (FAA-AST) regulates commercial launches and re-entries. However, under the current "learning period" approach, FAA-AST primarily requires operators to inform participants of the risks and obtain written informed consent, rather than enforcing detailed medical standards for passengers [9,11]. Flight crew with safety-critical responsibilities must hold at least a second-class FAA aeromedical certificate, but there is no equivalent licensure for passengers [8,24].

Multiple expert groups and FAA-sponsored studies have proposed medical acceptance guidelines for commercial spaceflight participants and commercial flight crew, but these remain non-binding, and there is no single, consensus standard adopted across industry [8,23–25].

Recent reviews have outlined candidate frameworks for suborbital and orbital participant screening. Existing guidance has been synthesised into mission-specific screening protocols that consider cardiovascular risk, pulmonary disease, musculoskeletal limitations, and neuropsychiatric stability in the context of expected G-loads and cabin environment profiles [8]. Other work from FAA Centers of Excellence and NASA explores how terrestrial cardiovascular and occupational standards might be adapted to commercial spaceflight [23–25].

Common themes include:

- Recognition that baseline risk in the commercial population will be higher than in professional astronaut corps [7,8].
- Emphasis on structured screening by physicians with aerospace medicine expertise, often in partnership with local clinicians [8,23].

- The need for ongoing data collection to refine risk estimates, as large-scale commercial operations are still nascent and empirical data limited [9,23].

4. From Selection to Screening and Certification

It is helpful to distinguish three related but distinct processes:

- Selection – choosing a small subset of candidates to form a professional astronaut corps, based on stringent, multi-dimensional criteria aimed at minimising mission risk and maximising long-term performance.
- Screening – identifying individuals in a larger population who meet minimum thresholds of safety and capability for a specified mission profile.
- Certification – formally attesting that an individual has completed required screening and training and is acceptable to fly given a defined risk envelope.

Traditional agency astronaut processes encompass all three but are dominated by selection. Commercial operators, by contrast, primarily engage in screening and certification of paying customers. Rejecting large fractions of applicants on stringent criteria is economically and reputationally unattractive yet failing to screen adequately could result in catastrophic in-flight events that threaten company survival and the wider industry [9,25].

Commercial spaceflight introduces several specific risk trade-offs:

- Higher baseline medical risk: Participants may have controlled coronary artery disease, prior thoracic surgery, vestibular disorders, or psychiatric histories that would disqualify them from agency astronaut selection. Yet many can likely fly suborbital or short-duration orbital missions with acceptable risk if properly evaluated and mitigated [22].
- Short training duration: Spaceflight participants typically undergo days to weeks of training, not years. Screening must therefore account for limited time to develop operational competence, emergency skills, and team cohesion [8,26].
- Mixed crews: Vehicles may carry both professional crew and passengers, with complex interactions between crew workload, emergency procedures, and passenger behaviour under stress [11,25].

Commercial screening currently seeks to be risk-informed rather than risk-eliminating, accepting a higher probability of medical events than traditional astronaut corps while avoiding predictable, preventable incidents [8,23].

At the same time, there is growing societal and agency pressure for inclusion in human spaceflight, as exemplified by ESA's Parastronaut Feasibility Project [19,20]. Commercial spaceflight could, in principle, democratise access; yet overly conservative screening may perpetuate exclusion of people with disabilities or chronic conditions despite manageable risks [27].

Ethically robust screening must therefore:

- Be transparent about the basis for disqualification.
- Distinguish between relative risk (higher than that experienced by a young, healthy astronaut but still within an acceptable absolute probability of in flight harm for a given mission) and unacceptable absolute risk (high probability of acute, mission-compromising events such that flying would be ethically indefensible even if the individual is willing to accept it) [8].
- Consider reasonable accommodations and mission tailoring (e.g. seat configuration, life-support redundancy, medical monitoring) where feasible [19,27].

5. Toward a Risk-Informed Framework for Commercial Astronaut and Customer Screening

Drawing on agency practice, commercial guidance, and experience from other high-risk industries, a pragmatic framework for commercial human spaceflight could involve three main elements.

First, screening and certification should be explicitly mission- and role-specific, rather than generic. For example:

Mission class A – Suborbital tourism: Short (<1 hour) flights with high ascent/descent G-loads, minimal cabin mobility, short duration microgravity and no EVA.

Mission class B – Short-duration orbital: Multi-day free-flyer or space station visits without EVA, with moderate ascent/descent G-loads and moderate duration microgravity and cabin mobility.

Mission class C – Long-duration orbital or deep space: Weeks to months, more complex operations, with moderate ascent/descent G-loads, long duration microgravity exposure and possibly including EVA.

Within each mission class, roles can be defined:

Professional crew (operators/pilots): Safety-critical, requiring standards closer to traditional astronaut or commercial pilot criteria.

Mission specialists / private astronauts: Non-pilot roles with operational tasks.

Spaceflight participants (tourists): Minimal operational responsibility.

Medical and psychological thresholds can then be tuned by class and role, for instance, accepting higher cardiovascular risk for moderate-G, short-duration Class B tourist missions than for Class A flights where slightly higher return G-loads are possible, or for crew with safety-critical duties [8,23,24].

Second, screening can be structured as a layered process, progressing from low-cost pre-screening to more intensive evaluation:

Pre-screening (remote):

Structured questionnaires covering cardiovascular, pulmonary, neurological, metabolic and psychiatric history, medications, prior surgeries, and functional limitations.

Automated rules to flag clear contraindications (e.g. unstable angina, recent myocardial infarction, severe COPD, uncontrolled epilepsy, current substance misuse) based on consensus guidelines [8,11,23,24].

Targeted medical examination:

Conducted by physicians with aerospace medicine training or under their guidance.

Includes for example focused physical examination, ECG, basic laboratory tests, and where indicated, stress testing, pulmonary function tests, imaging, and ophthalmic evaluation (especially for orbital missions).

Assessment of functional reserve (e.g. ability to tolerate emergency egress, donning of safety equipment, brief high-workload tasks) [8,26].

Psychological and cognitive screening:

Short, validated tools assessing mood, anxiety, and major psychiatric history.

Cognitive tasks targeting situational awareness, decision-making under stress, and the ability to follow complex instructions, scaled to role (more extensive for private astronauts than for tourists) [5,6,21].

Training-embedded evaluation:

Use of centrifuge profiles, high-fidelity cabin simulations, and emergency drills not only for training but to observe participant tolerance and behaviour [8,26].

Opportunity to withdraw or postpone participants whose response to G-loads, or psychological stress indicates unacceptable risk, even if baseline medical tests were reassuring.

At each layer, decisions can be framed in terms of mission-specific risk categories (e.g. “acceptable”, “acceptable with restrictions/mitigations”, “not acceptable for this mission class but potentially suitable for lower-risk missions”).

Third, the outcome of screening should be formalised as certified, with clear assumptions about:

- **Mission class and role** for which the certification is valid.
- **Time validity** (e.g. 6–12 months, shorter for higher-risk profiles).
- **Required mitigations** (e.g. additional in-flight medical monitoring, seating near access routes, supplemental oxygen availability).

Longitudinal data collection (pre-, in- and post-flight) should be embedded to refine screening criteria:

- Systematic recording of in-flight medical events, near-misses, and performance issues.
- Post-flight health follow-up for participants with notable pre-existing conditions.
- Pooled, de-identified datasets shared across operators and regulators to enable more robust risk modelling, analogous to safety-reporting systems in commercial aviation [9,23,25].

Over time, a feedback loop such as that proposed can narrow the current gap between traditional astronaut standards (well codified but tailored to elite professionals) and commercial guidelines (fragmented and largely consensus-based).

6. Implications for Agencies, Operators, and Regulators

For space agencies, the commercial era represents an opportunity to translate decades of experience with astronaut selection into reference standards and training for commercial providers. Space agency selection processes will likely remain more stringent than commercial norms, but elements such as structured cognitive assessment, mission-specific physical performance tests, and psychological support models can inform industry best practice [1,3,19].

For operators, adopting a transparent, risk-stratified screening and certification framework can:

- Reduce liability by demonstrating due diligence [25].
- Protect brand reputation in the event of inevitable in-flight medical incidents [8].
- Enable more inclusive participation by moving beyond binary “fit/unfit” judgements to nuanced “fit for this mission with defined mitigations” [23,27].

For regulators, the anticipated end of the current “learning period” in US commercial human spaceflight raises the question of when and how to introduce more prescriptive standards for participant safety [9]. Rather than directly imposing agency-level astronaut standards on commercial customers, regulators may choose to:

- Mandate minimum screening processes while allowing flexibility in implementation.
- Require data reporting and safety-management systems analogous to those in aviation [11].
- Facilitate consensus-standard development through organisations such as ASTM (American Society for Testing and Materials), or ISO (International Organization for Standardization), informed by agency and industry input [25].

7. Conclusions

Traditional astronaut selection is the product of six decades of experience with high-risk, government-led spaceflight. It is deliberately exclusive, designed to minimise mission risk for small, professional crews operating in extreme environments over long durations. Commercial human spaceflight, by contrast, aims to open access to a much broader and more heterogeneous population, under regulatory regimes that currently give substantial freedom to operators while emphasising informed consent. The challenge for the “new era” is not to transplant agency astronaut selection wholesale into the commercial realm, but to adapt its core principles (mission-specific risk assessment, multi-domain evaluation, and iterative refinement) into scalable screening and certification processes that are economically, ethically, and operationally viable for commercial operators. A stratified framework that differentiates mission classes and roles, uses layered screening, and embeds continuous data-driven feedback offers a pragmatic path forward. As commercial flight rates increase and diverse participants begin to accumulate flight histories, collaboration between agencies, operators and regulators will be essential. Only by integrating government experience with commercial innovation can we realise a future in which human spaceflight is both more widely accessible and acceptably safe.

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Abbreviations

The following abbreviations are used in this manuscript:

AST – Office of Commercial Space Transportation (FAA)

CRS – Congressional Research Service

EVA – Extravehicular Activity

ESA – European Space Agency

FAA – Federal Aviation Administration

G – Acceleration due to gravity (g-load)

ISS – International Space Station

JAXA – Japan Aerospace Exploration Agency

LEO – Low Earth Orbit

NASA – National Aeronautics and Space Administration

NASA-STD-3001 – NASA Space Flight Human-System Standard

SFP – Spaceflight Participant

US – United States

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