SD2905 Human Spaceflight
Design of a Space Hotel - Blue Team
Mission Teams, Logistics and Operations

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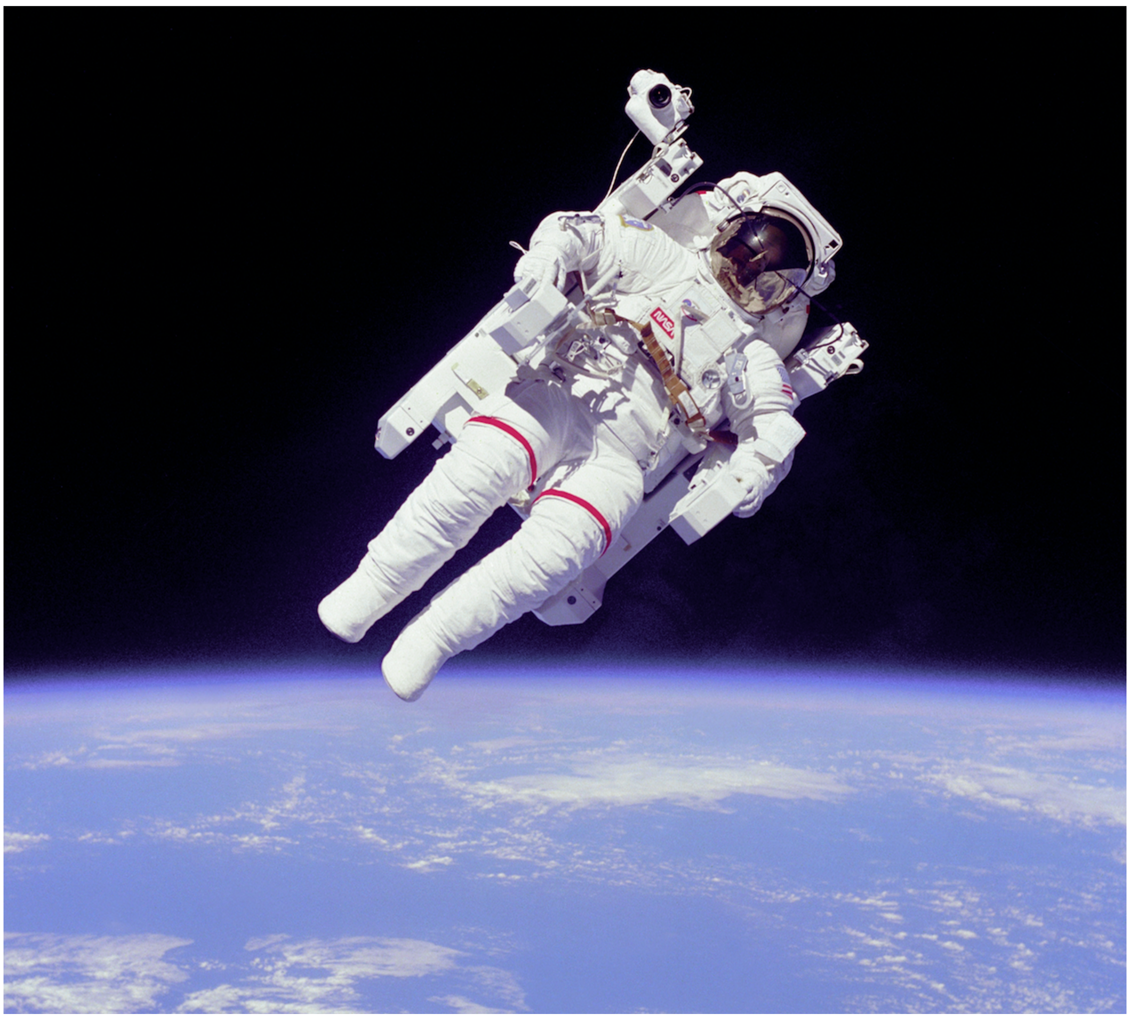

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I. Introduction

Logistical planning is critical in ensuring the smooth running of a project. This entails the organization and implementation of operations required for its start-up and upkeep. The paper and work behind it was done keeping this in mind and is concerned with the construction, maintenance, supply and transportation to and from the hotel.

II. Initial Selections

In order to begin with the design and planning for the hotel a few values must be set. These will have a big influence on the rest of the project and define the design. In this case these values are the length of stay, number of crew, the number of guests and the frequency of launches.

A. Length of Stay

A number of different considerations had to be made when the decision on length of stay was made. The longer the stay, the more time guests would have to do activities in space, however, depending on the size and modules of the hotel, guests may find it hard to find things to do in longer stays. There are also a number of medical aspects which affected the decision, since longer stays could require guests to perform regular exercise or extra radiation protection. Shorter stays would not be too feasible either because of the high launch costs associated with taking people into orbit. Keeping these considerations in mind, the length of stay was chosen to be 7 days which would be a good middle ground as it is long enough to take in the 'space experience' while not being too long to become boring.

B. Guests and Crew On-board the Station

Allowing more guests on the hotel would, in the long run, allow for a higher potential profit. However this would result in development of a larger hotel, with bigger modules, which would lead to more complex systems and structural requirements on the hotel. This means that the development costs for these modules may be much higher. Another consideration when deciding on the amount of guests is the launcher capsules available to be used. Launch costs are the highest of any other cost by a big margin, so reducing the number of launches will allow for more profit to be made. Keeping this in mind (minimizing the number of launches per stay) and looking at launchers which will be available in the near future, a maximum capacity of 7 people per launch is available. Keeping in mind that at least one pilot would need to be on board, both for safety and to direct passengers, the capacity for guests per launch and therefore for each stay would be 6.
In the case of crew, having less crew would result in less expenses on the hotel. However guests would need an adequate amount of crew to be able to take care of them during their stay and make sure that their needs are fulfilled. This means that one crew member to take care of all 6 of the guests would not be suitable. Since one pilot is also required to bring up, and return down with the guests, at least one would need to stay on the hotel. Leaving a single crew on the station alone would not be advisable since if they became incapacitated, no one would be there to help. This lead to the total permanent crew on board the hotel to be 3.

C. Frequency of Launches

The main element to consider for this was the duration of stay. If possible the number of launches would be maximized allowing for more guests to stay at the hotel within its lifespan. However preparation of launchers, maintenance of the hotel, length of stay and launch site availability all decrease the frequency of launches possible. Taking these into account it was decided that 25 launches per year would, although being slightly ambitious, be sufficient time. This means that of the 52 weeks a year, the hotel would be empty every other week, and once a year for a 3 week period where more demanding maintenance could be performed.

III. Orbit Selection and Launch site

For the hotel orbit, it has been decided that the best option is to use the same orbit as the ISS is currently in. The orbit parameters are:

Table 1: Orbit Parameters

Altitude $[km]$	**Orbital Speed** $[km/s]$	**Inclination** $[deg]$	**Eccentricity**
350-460	≈ 7.7	51.6	≈ 0

The criteria used to choose this orbit were the following:

- It is reachable from main launch sites (Guyane, Cape Canaveral, Baikonur...) due to its inclination.
- The launch procedures, logistics and maneuvers are well documented, since there have been multiple launches to this orbit during the ISS operation.
- Re-entry procedures are possible and have been already performed for both capsule landing and winged vehicle runway landing (Examples with Soyuz and Space Shuttle).
- Orbital phenomena and possible harmful effects (micrometeoroids, radiation, earth magnetism, space debris...) have been fully studied, and with plenty of data from the whole ISS period of operation, for both hardware, systems and also humans.
- Plenty of control centers are already prepared on ground to establish communication with space vehicles in this orbit.
- From a touristic point of view, the orbit covers almost all major Earth territories, at both day and night.

The launch sites could in fact be all those with a latitude smaller than the orbital inclination (51.6^o). But the main considered ones, for their equipment and importance in space missions could be Guyane, Cape Canaveral and Baikonur. Also considered was the new launch site which is under construction by SpaceX at Boca Chica Village which is set for completion in 2017. This would be the ideal site since the launchers being used are produced by SpaceX themselves and the other launch sites would probably be busier with other launch operations since they are not private sites.

IV. Selection of launch vehicle

For the selection of the crew capsule and launcher we compared the cost per hotel guest that could be carried into orbit. The comparison involves currently available technologies and those that are in development but are available in the near future.
We took into account that one seat in each launch vehicle is occupied by a pilot and can therefore not contribute to the profit. As seen from Table 2 the launch vehicle with the lowest price per guest is the Dragon V2 by SpaceX.
We further considered the payload mass and payload volume as soft selection criteria. However, they are high enough in all considered options and therefore the final choice for our crew vehicle is the Dragon V2 by SpaceX.

Table 2: Capsules with launch vehicles

Launch Vehicle	**Cost/Guest** [\$M]	**Mass** $[tons]$	**Volume** $[m^3]$	**Crew** $[-]$
Dragon V2	24 [4]	3.3 [5]	10 [5]	7 [5]
Orion	60 [6]	-	9 [7]	6 [7]
Dream Chaser	42 [8]	11.3 [9]	16 [9]	7 [9]
Starliner	-	-	-	7 [10]
Soyuz	70 [11]	7.1 [12]	5 [12]	3 [12]
Shenzhou	55 [13]	7.8 [14]	14 [14]	3 [14]

The turnaround time for the Dragon V2 is currently 14 days without it being fully reusable, which is also ideal for us considering our intentions to fly up tourists every two weeks, or 14 days.
For the construction launch vehicle, Falcon Heavy has been chosen. Other cargo launch vehicles were evaluated (Soyuz, Ariane 5, ULA Atlas V) but SpaceX Falcon Heavy was the most cost effective one of all. It takes 53t to LEO at a maximum cost of 90M dollars. This cost is much lower compared to Ariane 5 (160M dollars), for example. Of course, this would depend on SpaceX delivering the promised service in the required period of time. Also, all the hotel design has been done taking into account the dimensions of the Falcon Heavy payload fairing.

V. Hotel Operation

For the duration of operation, from the completion of assembly, to decommission, the intended use schedule can be seen below. This diagram show how the tourist and astronaut rotation would be happening.

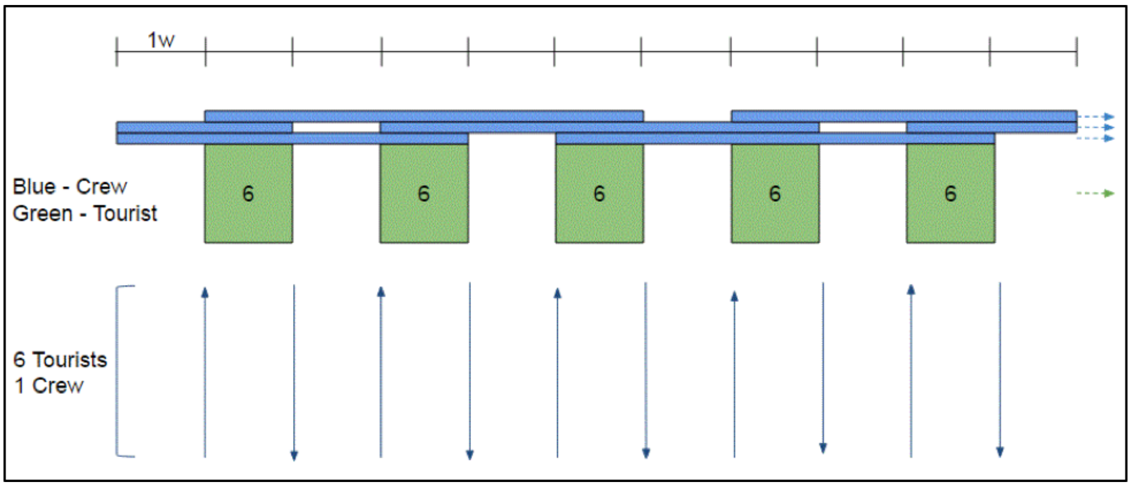

Figure 1: Operation Schedule

To begin, two astronauts would be sent up a week before the first tourists to prepare the hotel, and bring up the spare capsule so there are enough available for everyone on the station. After that, a capsule with six tourists and one astronaut would be sent up for a week, after which the six tourists, and a different astronaut would be de-orbited. This would pattern would restart again a week after de-orbit, allowing for each astronaut to have a maximum stay of 5 weeks on the station per rotation.

A. Crew logistics

As can be seen in Figure 1, there will be 3 crew members on the station whenever there are guests. Each of them will work on 5 week shifts in space, two shifts per year. This was chosen because it fits with a regular job workload over a whole year, taking into account that the time they spend in space is 24h on-call job.
If the launch schedule goes as planned, 25 annual launches are expected. This means that 12.5 crew members will be needed to cover the entire operation. To take into account security margins, the number has been set to be 14 hired crew members.
The two crew members that are permanently on the station will perform maintenance operations, and even possible privately funded science experiments. This way we maximize the number of guests we can bring up and down in one launch, and also the hotel operations are ensured to run smoothly.
The 11 or 12 crew members on ground will work on mission operations, such as covering the CAPCOM position at mission control, training clients for their space trip and performing debriefing activities with returning clients.

B. Ground control

There will be one main site for ground control, located in the US. It has been estimated that 16 people will be needed to cover all positions. In 8 hour shifts, and considering that we need to double each position (to consider time off and sickness), this means 96 hired control staff. They will be divided in the following positions:

- Flight Director
- Attitude determination and control officer - ADCO
- Power, Heating, Articulation, lighting control officer - PHALCON
- Thermal Operations and Resources - THOR
- Trajectory Operations Officer - TOPO
- Public Outreach - PAO
- Structures and mechanical - OSO
- Communications RF Onboard Networks Utilization Specialist - CRONUS
- Environmental Control and Life Support System - ECLSS
- Planner - OPSPLAN
- Cargo Integration Officer - CIO
- Capsule Communication - CAPCOM
- Extra vehicle activities - EVA
- Biomedical Engineer - BME
- Ground Control Systems - GC
- Robotics Operations - ROBO

VI. Hotel construction

The whole hotel construction will be done over a period of 15 weeks if there are no launch delays. It will be performed by automatic docking systems as well as a team of 4 astronauts performing EVA activities. The construction schedule and launch sequences are as follows:

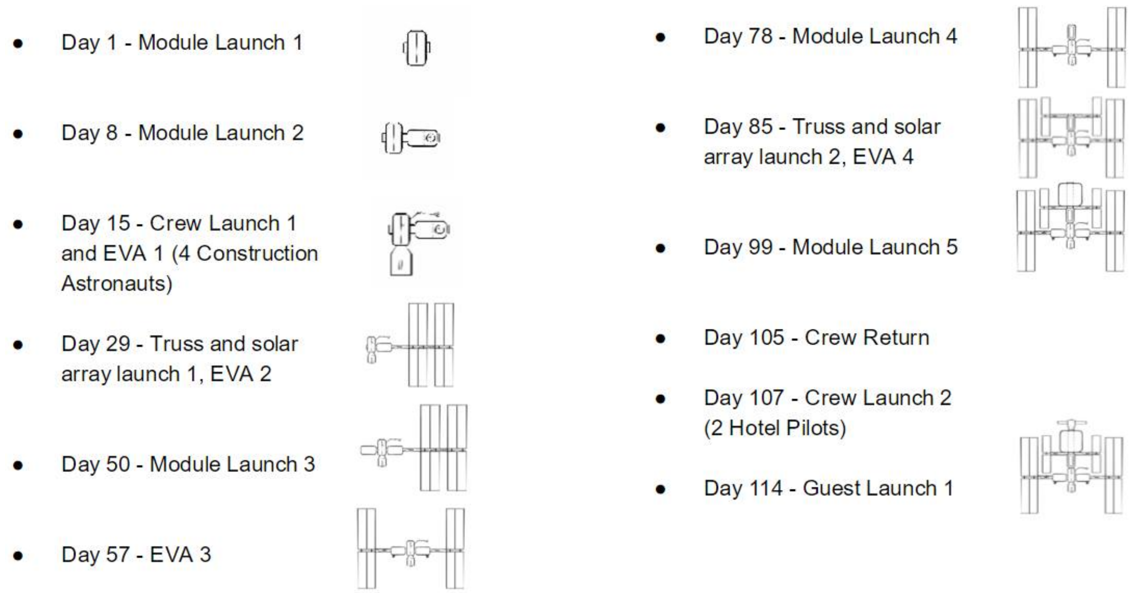

Figure 2: Construction schedule

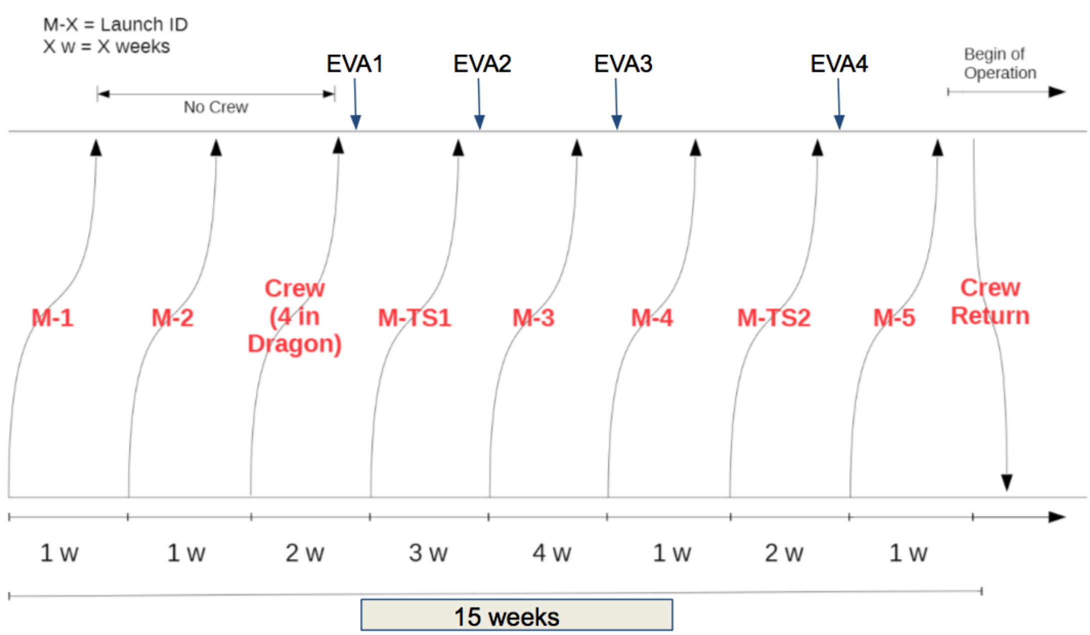

Figure 3: Launch logistics

The construction will then go as the schedule indicates. The first two modules will be launched separately and assembled by automatic rendez-vous. After that, with the first crew launch, the 4 astronauts will perform four sets of EVA's through the next 13 weeks to assemble and set up the whole hotel. Finally, when it's fully operational, these astronauts will come back and the first hotel crew members will start operating the spacecraft, ready for the first guests to arrive.

VII. Hotel Maintenance

In order to keep the hotel operational and to ensure that guest stays run as smoothly as possible maintenance on the hotel must be done regularly. Due to the schedule of the flight plan, there is a week in between each guest week where routine maintenance could be done, where the astronauts would check that all equipment is calibrated and working correctly, check the outer surfaces of the hotel and capsules for any flaws, make sure all facilities inside are functional and make sure the guest' quarters are prepared for their stay for the next week. Things as air filter checks, thermal control, refueling thrusters and general required reparations inside the hotel will be done in this non-guest periods of time.
More rigorous and complex maintenance would be done during the 3 week 'break' period of the hotel. This would cover the changing of some fundamental parts of the hotel such as changing a defective CMG (control moment gyroscope), refurbishment of a module or addition of new modules. During this time spare parts could be brought up with a new launch if they do not fit into the dragon module with the last guests.
Every now and then the hotel would also require a boost of speed in order to counteract the effect of drag. The orbital decay at this orbit would be around 100m per day. This would result in loss of 0.06m/s per day. Using the electric thrusters chosen, the fuel required was calculated to be about 4kg per month. This result is a low value which would be very easy to supply to the hotel with the weekly launches.

VIII. Emergencies

When developing a space hotel, one must always consider the chance that an emergency off nominal event will occur with either the guests, the crew or the station. The implications of various situations arising from these three categories can be found in the sections below.

A. The Guests

In the event that a guest becomes ill or injured while on the station, the response ultimately lies in the severity of the situation. Upon identification of a problem, the status of the guest is evaluated by the crew, and ground control if further medical expertise is needed. Based on the evaluation, a decision can be made on if the guest may remain on the station, or needs to return home for medical care.
In the case that the issue is not severe, and it has been determined that the guest can safely remain at the hotel, the visit will continue as planned. Should they be sick with an infectious disease it will also be possible to quarantine them as the risks of infection to others are greatly increased in the space environment and treatment for complications is much harder to access.
In the event, however, that one of the guests is so sick or injured that they must be brought down, it will result in a complete termination of the visit for all guests. This decision is based on the ability to continue regular scheduled service of guests to the hotel. The reasoning behind this decision is that if the sick guest is brought down with one astronaut, and it would take at least one more astronaut to take down the remaining guests at the end of their stay, it would leave any potential remaining astronaut without an emergency escape capsule as both capsules would be back on earth. On top of that problem, it would leave the station short staffed, and the following set of guests would be at the station without enough seats to escape the station. This decision is also motivated by the fact that flights are booked months, if not years in advance with the launch provider, and one cannot simply call them and ask them to add another launch next week.
In the case of an aborted vacation, all of the guests will be rescheduled to fly again at the soonest convenience at the cost of the company, covered through insurance.

B. The Crew

In the event that a crew member becomes sick or injured, the same initial steps would be followed, with the assessment of the severity of the situation. While the case where the astronaut may stay in orbit is the same, the case of needing to descend would be different.
In the case of needing to bring a sick astronaut back to earth, the windfall would pose a rippling effect on to future flights. This is because everyone would have to de orbit, as it would take at least another astronaut to take down the sick one, leaving the final astronaut to take down the remaining crew. This means that in order for regular operations to continue, the following launch would need to be crew only, meaning that that

launch guest crew would need to be canceled and everyone rescheduled for a future flight date to preserve the integrity of the remaining future flights and bookings.

C. The Station

In the case of an emergency such as a fire, toxic gas leak or hull breach, everyone would be immediately evacuated to the half of the station that was still safe, and the other half would be sealed off. Following this step, the guests plus pilot would be sealed into their capsule in preparation for an evacuation while the remaining two astronauts dealt with the situation. Should the situation be successfully resolved, the vacation will continue as planned, however if there has been too much damage, they would be returned to Earth. Following their departure, if the departure of the remaining two astronauts was needed as well, they could remotely fly the second capsule around to an available air lock on the safe side of the station and use it for evacuation. All future flights would be postponed, pending an investigation and repairs.

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