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# The Emirates Mars Mission (EMM) Journey to Mars – COVID-19 Impacts Challenges and Opportunities

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**Abstract**

After a seven-month cruise phase, the Emirati led Emirates Mars Mission (EMM) successfully achieved Mars orbit on February 9th, 2021. The successful entry into to Mars orbit was even more remarkable given the challenges caused by the COVID-19 pandemic. All facets of the program had to adapt to a world trying to slow the spread of COVID-19. The EMM team successfully navigated through ever changing travel logistics for people and hardware. The team adapted to the challenging aspects of life in quarantine while transitioning to a flight operations concept with many key individuals working from home. This paper will discuss the unique challenges the EMM mission overcame to achieve the goal of becoming the first Arab mission to orbit another planet.
**Keywords:** Mars, EMM, Hope, Al Amal

**Acronyms/Abbreviations**

| | |
|---|---|
| COVID-19 | Coronavirus Disease 2019 |
| EGSE | Electrical Ground Support Equipment |
| EMM | Emirates Mars Mission |
| DSN | Deep Space Network |
| HEPA | High Efficiency Particulate Absorbing |
| ISP | Internet Service Provider |
| LASP | Laboratory for Atmospheric and Space Physics |
| MBRSC | Mohammed Bin Rashid Space Centre |
| MERV | Minimum Efficiency Reporting Value |
| MHI | Mitsubishi Heavy Industries |
| MOC | Mission Operations Center |
| MOI | Mars Orbit Insertion |
| NASA | National Aeronautics and Space Administration |
| PCR | Polymerase Chain Reaction |
| PPE | Personal Protective Equipment |
| SME | Subject Matter Experts |
| UAE | United Arab Emirates |
| USA | United States of America |
| VNC | Virtual Network Computing |
| VoIP | Voice Over Internet Protocol |
| VPN | Virtual Private Network |
| WHO | World Health Organization |

## 1. Introduction

On January 30th 2020, the World Health Organization (WHO) declared the coronavirus disease 2019 (COVID-19) outbreak a public health emergency of international concern. The WHO then designated COVID-19 as a global pandemic on March 11th 2020. In response to the global health crisis governments and organizations around the world began to impose restrictions on travel and limiting the number of individuals who could work in close proximity to

each other. At this time the EMM spacecraft, known as Al Amal (Hope, in English), was fully assembled in the clean-room at the Mohammed Bin Rashid Space Centre (MBRSC) in Dubai (Figure 1-1). A team of engineers from the

**Figure 1-1 Al Amal in the MBRSC clean room at the onset of the pandemic (Photo Credit: MBRSC)**

MBRSC and the Laboratory for Atmospheric and Space Physics (LASP) were working through the final checkout procedures prior to shipment to Tanegashima, Japan for launch. Table 1 lists a number of key events that occurred between the onset of the pandemic and the arrival of EMM at Mars.

**Table 1: Key Events**

| Date | Location | Event |
|---|---|---|
| **1/20/2020** | USA | First confirmed case of COVID-19 in the US. |
| **1/30/2020** | WHO | Declaration of a public health emergency of international concern (COVID-19). |
| **3/11/2020** | WHO | Declaration of COVID-19 as a global pandemic. |
| **3/13/2020** | Europe to USA | Travel ban from Europe to USA. |
| **3/15/2020** | Dubai | Cancelation of public events. |
| **3/16/2020** | Colorado | Public health order closing restaurants, theatres, gymnasiums and casinos. |
| **3/17/2020** | USA to Europe | Travel ban from USA to Europe. |
| **3/18/2020** | Colorado | LASP transitions to a remote work environment with only essential personnel on site. |
| **3/19/2020** | Colorado | Gatherings limited to no more than 10 people. |
| **3/19/2020** | UAE | Special Visas are required to enter the UAE from the USA. |
| **3/22/2020** | UAE | The final members of the transportation team depart Colorado for Dubai. |
| **3/24/2020** | Boulder, Colorado | Stay at home order issued for Boulder County (location of LASP), travel is only authorized to support essential activities. |
| **3/26/2020** | UAE | Curfew goes into effect in Dubai. Citizens and visitors must have permission to travel during curfew, enforced by traffic cameras. |
| **3/28/2020** | Boulder, Colorado | Employees supporting EMM launch readiness are declared essential employees. Social distancing (6 feet) still required when on site. |
| **3/31/2020** | Japan | LASP spacecraft receiving team departs for Japan (14-day quarantine requirement on arrival). |
| **4/3/2020** | Japan | Commercial travel from the US to Japan is severely restricted, All US travellers require pre-departure visas. |
| **4/5/2020** | Japan | MBSC spacecraft receiving team departs for Japan. UAE charters aircraft to move S/C receiving team from the UAE to Japan (14-day quarantine on arrival). Minimizing exposure risks. |
| **4/21/2020** | UAE-> Japan | EMM spacecraft ships from the UAE to Japan. |
| **4/28/2020** | UAE | Original Ship date. |

| | | |
|---|---|---|
| **4/29/2020** | Japan | Commercial travel from the UAE to Japan denied for non-Japanese citizens. |
| **7/14/2020** | Japan | Launch Period Opens. |
| **7/19/2020** | Japan | Al Amal Launch (After several weather delays). |
| **8/12/2020** | Japan | Launch Period Closes. |
| **2/9/2021** | Mars | Al Amal Mars Orbit Insertion. |

The EMM team was able to find solutions to many challenges during this period. Observations and lessons learned from the team have been collected and grouped into five categories: human factors, enabling technologies, transportation, facilities and management.

## 2. Human Factors

The leading contributor to the successful arrival of Al Amal at Mars were the dedicated people of the EMM team (Figure 2-1) and those who supported them throughout this time of great uncertainty. At the onset of the pandemic, there were many unknowns about how the virus was spread and how to treat those who became infected. With people working in many locations around the globe, often times far from home, it was very important for those traveling to know that the program was committed to finding them a way home if it became necessary. The travellers received assurances from senior members of the UAE government that they would do everything possible to return people home. These assurances carried a significant weight with the travellers as they were coming from people who had been working with the program since the beginning. It cannot be overstated how much this assurance reduced the anxiety of those on travel and allowed the them to focus their attention on the work that needed to be done.

**Figure 2-1 EMM team photo taken during the Critical Design Review (Photo Credit: MBRSC)**

In the time leading up to the spring of 2020, the EMM team had demonstrated the ability to adapt and overcome many difficulties. Dealing with the impacts of COVID-19 became another challenge. The team was able to successfully adapt to a new working environment with most people working remotely from newly established home offices. More and more staff members became experts not only in video conferencing tools, but also incorporating various instant messaging applications in their daily routine. Walking down the hall and knocking on someone's door was replaced with an instant message and spontaneous video conference call.

Travel plans changed drastically in the early days as governments adjusted travel policies. Given the uncertainties surrounding international travel, some people significantly extended their time away from home because the program did not know when it would be possible to get additional resources on site. Having the ability to video conference with family back home helped to ease the strain on those away from home and their families. On other occasions people had to prepare to depart for an extended trip with less than 24 hours notice. Special visas for international travel often came with specific requirements as to what flights were authorized for travel. Consequently, when the travel opportunity presented itself, staff had to be ready to depart within a few hours.

A single COVID positive test result from someone on the team could result in a significant number of people being forced into quarantine. Given the limited launch period for an interplanetary mission, and the limited margin remaining in the schedule, a positive COVID test on the team, would have likely impacted the number of launch opportunities. It was possible that this could cause the mission delay launch by more than two years (the launch window for Mars only occurs every 26 months due to planetary alignment). Nobody on the team wanted to be patient zero. This led to the team being very proactive in practicing social distancing, good hand hygiene, and following other COVID precautions.

The UAE government was very proactive in managing the pandemic. They were quick to implement protective measures across the country to limit the spread of COVID-19. They were able to source and distribute personal protective equipment like masks, gloves, hand sanitizer and alcohol wipes. Additionally, within the UAE there is a culture of following the rules as laid out by the government, which was backed by strict enforcement of COVID regulations. This helped to reduce the spread of COVID within its borders. This also helped to reduce the likelihood of someone from the team contracting COVID during the pre-shipment activities.

Strong teamwork was critical to the success of the mission during this time. The EMM team was relatively small for an interplanetary program. This had several side effects that proved beneficial when dealing with the impacts of COVID. In the original plan, people were required to support several different activities. This resulted in individuals having broad experience and diverse skillsets. During the period of restricted travel, this diversity of skills allowed the team to be successful with fewer people physically on site. Additionally, the team had been working together for a number of years, and was laser focused on making the targeted launch date. The sacrifices the team had made earlier in the development and test program helped motivate them to push through the pandemic-created hurdles. Overall, the team was very invested in making the UAE's first mission to Mars a success.

The team members who travelled made significant sacrifices to support Al Amal on its journey to from Dubai to Tanegashima, Japan and on to Mars. The pandemic also required many sacrifices from those who remained at home. One of those key sacrifices were the many people who shifted their working hours at home to better align with the activities going on in Dubai and Japan. It was challenging enough for these individuals to remain at home and deal with impacts of COVID in their daily life and then on top of that, they were required to shift their work hours to be aligned with the work hours in Japan.

Good communication among the team was important to achieving Mars orbit. Working in a small team that had been together several years made it easier to pick-up on verbal queues when something was bothering someone. This was especially important given the shift from in-person meetings to teleconferences only. Without the ability to pick up on non-verbal cues, managers, team leads and co-workers needed to refine their listening habits. The video conferencing tool utilized by the program had the ability for individuals to turn on and incorporate built-in cameras. The project allowed individuals the choice of having their cameras on or off, with the overwhelming majority choosing to leave their camera off. In this case, the project relied on people listening to others, and trusted individuals to raise their concerns so that they could be addressed.

The EMM was very lucky that the onset of the pandemic occurred when it did. By March of 2020, the vast majority of work had been completed. The design and test phases were complete, and the mission was focused on the execution of the plans that had been made. In addition, the prime period for launch and operations readiness testing was just beginning. This made it easier to incorporate remote-work plans into the operations concept and allowed people to fully check out their work-from-home environment prior to launch. In an unexpected advantage, the pandemic significantly reduced the number of events on people's social calendars. School events for children were cancelled, weddings and other celebrations were postponed. For many, work became a distraction from life in a pandemic. In many cases this social void was filled by workplace relationships and to-do lists. In many cases, the work-life balance swung significantly in the direction of work. In the early phases of the pandemic, it felt like the overall productivity of the team increased, as people had fewer distractions. There were fewer vacations to work around, and with schools and daycare closed, there were fewer illnesses among the team resulting in fewer sick days. Some found that focusing on the task at hand, preparing for launch, allowed them to reduce the time spent worrying about the unknowns of the pandemic. During this time, it was important for management to be communicating to the team the information that was being used to make strategic decisions. These communications were essential to letting the team know that management was engaged, working COVID issues and that their safety was a top priority.

The members of the team with children of school age saw significant changes and new challenges in their daily routines. With most schools closed, and a shift to on-line learning parents became responsible for teaching and tutoring, fixing hot lunches, basic IT support for remote learning devices, training children how to use these devices effectively, monitoring recess and serving as guidance counsellors.

One of the unexpected challenges brought on by the pandemic, was the sense of isolation that some people felt. In many cases people were isolated from friends, family and co-workers. As the restrictions on social gatherings were

extended, this sense of isolation became worse. This was also compound by people being extra cautious for fear of catching COVID and potentially exposing other members of the team. It was important for management to watch out for those who were struggling, and to reach out and engage those individuals. It was amazing how helpful it could be to meet someone in a park and go for a walk and have an in-person conversation. Doing this while adhering to social distancing requirements provided a sense of relief for some.

## *3.* Enabling Technologies

### *3.1 Remote Telemetry Monitoring*

Early in the design phase, a decision was made to architect the system to have a dedicated network for monitoring real-time telemetry. In the baseline architecture, data would flow from NASA's Deep Space Network (DSN) to the high security command and control network at the operations facility. The telemetry would then be relayed down to the medium security operations support network. The operations support network could be reached from workstations in the secure areas of the facility as well as through a Virtual Private Network (VPN).

The VPN allowed the operations support team to access real-time telemetry monitoring and data analysis systems from their remote work location. In general, most staff setup Virtual Network Computing (VNC) connections to the operations support network. This allowed them to configure their environment as desired, and leave their session active on the remote computer between shifts. The team found that this setup was very efficient as they did not have to set-up nor tear down their configuration at the beginning or end of their shift.

The decision to baseline a stand-alone telemetry monitor and analysis network was made prior to the onset of the pandemic. However, its existence made it significantly easier to transition to an operations concept supported by a remote operations team.

### *3.2 Voice over IP System*

Prior to the COVID-19 pandemic of 2020 voice communications for satellite operations was a simple analog telephone line that was routed to a commercial multiplex server connected via hard lines to a physical communications box at each work station. The system was secured by requiring a controller to sit in a Mission Operation Center (MOC) and communicate to the ground network from an access-controlled location. This system worked well when people were on-site performing operations.

For EMM, the hardware supporting this legacy system was approaching end of life. Given the requirement to connect facilities in Dubai, Boulder and Tanegashima, it became desirable to investigate other options. With the increased availability of high-speed internet and a shift in the gaming industry to multi-player on line gaming, there were several more Voice Over Internet Protocol (VoIP) systems available than when the system was originally deployed. A trade study was performed between refreshing the legacy hardware and transitioning to a VoIP system. The end result was a decision to transition to the VoIP system as it offered more functionality at a lower price point. It should be noted that this trade was completed prior to the onset of the pandemic.

This decision turned out to be one of the keys in reducing the impact of COVID-19 restrictions. It made it much simpler to transition from a facility-based operations concept to one that had the majority of staff working from home. The system allowed engineers to connect from laptops, cellular phones, tablets and workstations from locations all across the globe.

One of the technical challenges in the implementation of the VoIP solution was getting it connected to the legacy voice system at the DSN. For EMM, it was necessary to create a system that would bridge the VoIP interface and convert it to an analog exchange with the DSN. At the time of the implementation the end-user application did not have the capability to make the transition from IP to analog. Consequently, the EMM solution required multiple software applications working in conjunction with each other to facilitate the transition from IP to analog and back.

The new system provided greater flexibility in the number of channels that could be created. This allowed the team to create channels that were specific to the various roles and spacecraft subsystems. The geographic separation of the team meant that conversations that would normally occur face-to-face in the room could quickly occur over a particular channel. As an example: if someone wanted to talk to the power lead, they could switch to the power channel and have a conversation. By moving these side conversations to a role-based channel, the team reduced the bandwidth and competition for the common lines.

In traditional voice systems there is a need for rigor in how communications occur over the voice network. These voice protocols help to maintain order on the system, and allows large groups of engineers to communicate efficiently. One downside of this approach is that it frequently makes the communications between individuals more sterile. People spend extra time thinking about how to say things with the proper protocol which slows down communications. The engineers wanted a system that would allow them to talk more freely. In essence to mimic the informal hallway

conversations that people have when working in the same facility. The team found that expanding the number of channels to enable these side conversations was very helpful.

The system was designed so that once the channels had been defined. Individuals could move around between the different channels as necessary. The system also allowed individuals to listen to multiple channels simultaneously, but were only allowed to talk on one channel at a time. Examples of the VoIP interfaces can be seen in Figure 2-2.

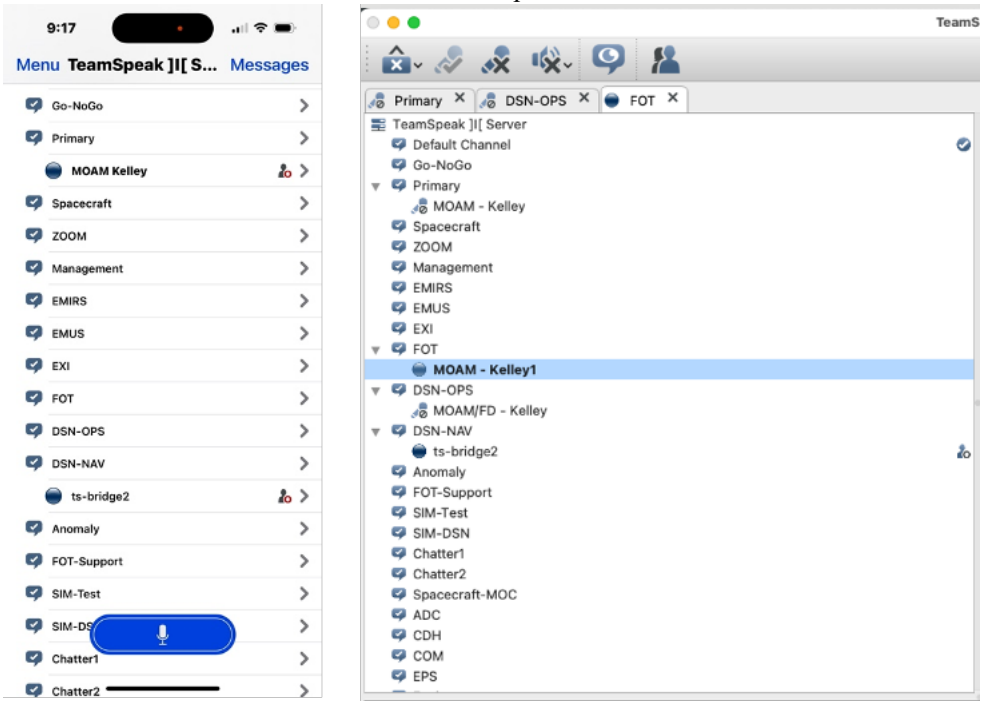


**Figure 3-1 Interface to VOIP system: mobile device (left), laptop/desktop (right).**

During the launch of the Al Amal satellite in July of 2020 the voice system was configured to have 28 internal channels, with two additional channels for communications to the DSN. It supported 284 end users utilizing 844 channel configurations with each user averaging three active channels during their session. In addition, there were two listen-only feeds provided to the media.

System security was ensured in two ways. The system required individuals to join the mission VPN before it could connect to the servers. Individual channels could also be protected by requiring a password before people could join.

The pandemic did move some of the capabilities identified in the trade from desired functionality to required functionality. The most obvious change was the requirement to support multiple platforms. This list included workstations, laptops, Apple iPhone/iPads, Android phones, and MS tablets, all of which could be attached to wireless networks or cellular connections.

The portability of the system to multiple devices and the ease of access allowed the team to work more efficiently. As situations occurred, the team could quickly move to one of the predefined channels to have large or small conversations while maintaining situational awareness of the primary operations channels. It was also common for people who were off shift to log onto the net and discuss the situation. Being able to do all this in one application improved the efficiency of the team.

The implementation of a VoIP communications system was a key enabling technology that made it possible to support EMM operations with a primarily remote workforce.

### *3.3 Collaboration tools*

Having the ability to collaborate with each other through on-line tools was the most important enabling technology used by EMM during the pandemic. Once again, the mission benefited from designs and implementations chosen long before the onset of the pandemic. From the very early days the program it was necessary deploy collaboration tools to allow engineers in Boulder and Dubai to work together. The team primarily leveraged the Atlassian tool sets to support a majority of collaboration.

The team used Confluence to allow multiple people to collaborate on documents. It was also very helpful in allowing people to find the most up to date information quickly.

Jira was used as a way to track the completion of activities. As an example: after a test was run on the spacecraft, a Jira ticket would be opened. Individuals would be tagged in the ticket with a request to review the data from the test and to document the results of their analysis to the ticket. Sometimes the analysis would include an attachment, and at other times a simple comment and signature would be sufficient. It was extremely helpful to have a single location where someone could go to see the conversations between team members, and to identify if/when all the sub-tasks had been completed so that the ticket could be closed.

Different types of tickets were developed, each with their own custom fields. This allowed the team to document information that was consistent with the work-flow for the particular ticket type. Deploying this system early during the integration and test phase allowed the work flows and ticket structure to mature as the program progressed, and allowed the team to get familiar with the processes that would then be used to support flight operations.

Having a mature collaboration and ticketing system in place prior to the onset of the pandemic made it significantly easier to transition to a remote work environment.

The VoIP system discussed previously is another example of a key collaboration tool.

Having an efficient way for the team to communicate and share visual content during meetings was critical to the success of the program. This ability to communicate was essential from the early days of the program due to having team members in Dubai and Boulder. Consequently, the team had very mature tools and were well trained in their use before pandemic restrictions forced people to work from home. These tools were heavily leveraged during the preparations leading up to launch when team members were distributed between Dubai, Tanegashima and Boulder. Due to COVID travel restrictions some Subject Matter Experts (SME) were unable to travel. As a result, several activities were supported with remote experts working with teams on-site to accomplish various tasks. In these situations, the expert would generate detailed procedures, then all people involved in the activity would walk-through the procedure prior to execution. A key lesson learned was to have an extra person, not involved directly in the activity to serve as the camera person during execution. This allowed the person performing the activity to focus on what they were doing and the camera person could adjust the viewing angle at the request of remote expert without interrupting activities.

### *3.5 Remote access during pre-launch testing*

Two key decisions were made early in the program that helped prepare the team for a remote work environment. The first decision was to allow for the spacecraft simulator environment to be fully functional from outside the facility. This requirement drove the design of the network and Electrical Ground Support Equipment (EGSE). In order to comply with the requirement a secure VPN was implemented to provide operators the required access. In addition, the EGSE was designed to allow operators to fully configure the system remotely. This would allow the operators to have full control of the system while offsite if needed. The pre-COVID baseline was to have test conductors on the test floor whenever the spacecraft or simulator were being run, but SMEs were given the opportunity to support remotely. In practice, the SMEs would monitor activities from their offices, and then relocate to the test floor for specific tests of interest.

The second key decision was to make the EGSE the same between the spacecraft test environment and spacecraft simulator environment. The primary drivers for this solution were to improve the efficiency of the test team and to give them more flexibility. From a pandemic perspective this decision meant that whatever functionality was available in the simulator environment was also available in the spacecraft integration and test environment. In addition, it allowed the team to practice the skills necessary to operate remotely and allowed the team to evolve the remote operations capability.

These two decisions went a long way to ease the transition to remote operations. Having the ability to fully configure and operate the spacecraft simulator from an offsite location was key to performing the final checkout of operational procedures prior to executing them on the spacecraft. Having the ability to monitor the spacecraft remotely allowed the travel teams to function with fewer people. In addition, having these decisions made prior to the onset of the pandemic meant that there was less down time as individuals transitioned to a work from home environment.

### *3.6 Risks*

Having a remote workforce during launch, commissioning, cruise and MOI did come with added risk. These risks centered around the reliability of people's remote work environment.

A loss of network connectivity from the staff's home office to the operations network was the most likely failure, although service from Internet Service Providers (ISPs) is generally very good, it is rare for any ISP to include a specific uptime or mean time to restore specifications in their service agreement to residential customers. As a result,

a number of options were considered. Management worked with individuals to identify their plan for recovering from a network outage. For some the plan was to re-locate to their office or the operations facility. For others the plan was to transition to a cellular hotspot for internet service. In the time leading up to launch each person was responsible for testing their contingency plan. The previously discussed VNC solution significantly reduced the bandwidth required to support operations over a cellular network. In most cases people were able to use their mobile phone as a hotspot and restore connectivity.

The second most likely failure was a commercial power failure. Most people were working from laptops in their home offices. Laptops have a built-in battery. As a result, in case of a power failure, most individuals' computers would continue to work. However, most individuals did not have back-up power for their home's internet connectivity. As a result, if someone lost power at home, they would lose their internet service. In this case the network outage contingency would be activated and people would switch to using their cell phone (also battery powered) as a hot spot.

In a lessons learned, it was found that as the pandemic and working from home dragged on for many months, the program started to see a higher battery failure rate in laptops as people started coming back into the office. This was likely caused by these laptops being constantly plugged in with the battery rarely going through a discharge cycle. As a result, it is recommended that for missions with long cruise periods with people exclusively working from home, that people incorporate a battery discharge cycle into their weekly work routine, and that they monitor the expected battery life in the event of a power failure.

## 4. Transportation

The simple task of moving people and things from one place to another became more challenging during COVID. Transportation schedules became very dynamic as the entrance requirements changed from day to day. It became very important to understand what the current requirements were for entry into various countries, as well as to try to understand what they were going to be 24 to 48 hours into the future. Having high level contacts at various governmental agencies was incredibly useful, and helped the program to stay one step ahead throughout this critical period.

### *4.1 Hardware*

It became increasingly difficult to move things from one location to another as the number of transportation options decreased. As the frequency of daily commercial passenger flights went down, the volume of cargo that could be moved by air was also reduced. Transportation options that used to be daily were often reduced to once per week. The increased competition made it harder to negotiate favourable terms. In addition, shipping warehouses would sometimes close down for extra cleaning if an on-site employee tested positive for COVID. Many organizations struggled to remain fully staffed during this period. All of these factors drove up shipping costs and extended delivery times. The program adjusted to this by shifting from a mentality of just-in-time, well-choreographed deliveries to just getting everything on site as soon as possible. In some cases, this resulted in having to deal with more things in local storage. Developing a plan for how to do this in a way that was efficient for future work-flows was extremely helpful.

**Figure 4-1 Al Amal shipping container being loaded onto the aircraft (Photo Credit: MBRSC)**

Keeping with the theme of getting things on site as soon as possible, it was also decided to move the spacecraft ship date from Dubai to Japan as early as possible (Figure 2-3). After reworking the closeout activities and shipping schedule, the team was able to move up the ship date by a full week. This was a remarkable feat given the complexity of the move (truck – aircraft – truck – ship – truck) and the need to split resources between Dubai and Japan during the two-weeks leading up to the ship date to account for the required quarantine periods. Arriving at the launch site early reduced the risk of future lockdowns preventing the move, as well as provided more time for the launch team to complete processing at the launch site. The extra time was extremely beneficial given that many of the activities in Japan were executed with the SMEs not on site. The extra time was used to allow more training and interaction between the SME and the hands-on personnel.

Transporting the spacecraft from Dubai to Tanegashima had its own unique challenges. An advance team of engineers, known as the receiving team, were sent to Japan two-weeks prior to the shipment of the spacecraft. This allowed those engineers to clear the two-week quarantine process prior to the spacecraft arrival. While the program tried hard to move people prior to the shutdown of commercial air travel, in this case it was not possible and a special charter flight was required to get the team from Dubai to Japan. The packing and transport team remained (Figure 2-4) in Dubai to prepare the spacecraft for shipment. A few members of the transportation team were allowed to accompany the spacecraft on the flight to Japan and were allowed to join the receiving team after completing a two-week quarantine in Japan. Activities at the departure airport were choreographed to minimize the mingling of the spacecraft support crew and the aircraft flight crew. Upon arrival in Japan, the transportation team assisted with the unloading of the spacecraft onto the tarmac and then headed off to complete their 14-day quarantine. The receiving team then assumed responsibility for the spacecraft and the transportation from initial entry into Japan, and on-to the launch site.

**Figure 4-2 Dubai packing and transportation team (Photo Credit: MBRSC)**

A hardware failure late in the integration and test program which required a flight component repair became significantly harder to deal with under COVID restrictions. The program had to work through the advantages and disadvantages of repair in Dubai or in Japan. Eventually it was decided to continue with the plan of transporting the spacecraft early and performing the change at the launch site. This allowed the team to stick to the path of getting to the launch site early, and gave the technical team more time to work out the details of the replacement. Unfortunately, this delay resulted in an additional challenge. In the original plan, technicians from the component supplier were going to be on site to perform the necessary rework. However, due to the continued evolvement of the pandemic, the vendor changed their travel policy to not allow their employees to travel internationally. Engineers from the MBRSC, LASP, Mitsubishi Heavy Industries (MHI) and the supplier all worked together to develop and train individuals from the EMM team on how to successfully change the damaged part. This included the use of an engineering model to practice on and facilitated the development of a way to test that the part was working after installation. The successful field replacement of the part, something that had only been attempted once before, was a testament to the ability of the entire team to use the resources available to overcome a problem. In a lessons learned from the experience, it is significantly harder to use a procedure that is written by someone else from another organization than using a procedure written by yourself. The engineering model, and having the ability to have video conferences with the vendor allowed the program to significantly reduce the risk associated with the activity.

*4.2 Personnel*

Travel restrictions made it significantly more challenging to support international travel. The program significantly reduced the number of individuals who would travel and frequently extended their time in the field. For those who did chose to travel, everyone voluntarily agreed to do so. The program would not have succeeded without the individuals who agreed to spend significant time away from family and friends and to live through as many as six weeks of quarantine. By the time the Al Amal was launched the mission had lost over one year of productivity to people in travel related quarantines.

Once travel restrictions went into place, it became much harder to travel. In many cases, special visas were required to allow individuals to fly into a foreign country. This required the program and their government counterparts to work together to get the appropriate approvals prior to departure. Travel during this time looked significantly different than standard international travel. Travelers had to be more self-sufficient as airports and airlines reduced the services available on long travel itineraries. In a lesson learned things like currency exchanges were not available to travellers upon arrival. This would cause travellers to go into a 14-day quarantine with no local currency. In order to reduce the likelihood of becoming infected while traveling, tickets were booked into less crowded portions of the airplanes (Figure 2-5). While helpful, many travellers reported flying on large wide body planes on international routes with less than thirty passengers. The comment from many was that they were able to social distance even while on the plane.

**Figure 4-3 Aircraft operating with minimal passengers (Photo Credit: LASP)**

The vast majority of the individuals on these flights were citizens returning home after being abroad. This led to some unexpected challenges upon arrival in international locations. Given the lack of international travellers, much of the standard multi-lingual support was not available. Announcements and other paperwork were frequently provided in the native language. This made it very challenging for those who were not familiar with the language in the host

country. This challenge was compounded by the fact that the travel process was completely different than anything anyone had experienced before. When people departed their home country, they did not know:

- How long would they be required to stay at the airport prior to being transported to a government quarantine hotel?
- What government quarantine hotel would they be moved to initially?
- How long would they have to stay at the government quarantine hotel?
- What would happen if there was an emergency at the government quarantine hotel?
    - Some travellers experienced an earthquake while in quarantine
- How would they get from the first quarantine hotel to the second quarantine hotel?
- What would the restrictions be inside the quarantine hotel?

There were a couple of lessons learned from this experience. Those who had to pioneer some of these routes found it extremely helpful to have a travel partner. Having someone you knew and trusted going through the process with you greatly reduced the anxiety associated getting through the process. Those who travelled later benefited greatly from having lessons learned passed on from the people who had gone before. Having someone from the host country help translate documents was extremely helpful. Ensuring this assistance was available prior to departure would have helped the early travellers.

As countries started to ban travel from the United States, the program started to consider options, like sending staff to other countries where they could quarantine for 14-days before traveling to the desired destination. As the pandemic spread, this option for travel became undesirable. It was challenging to understand what treatments were available to foreign nationals in the intermediate country in case of illness, and there was no guarantee that once the first quarantine period was over that travel would still be allowed from the intermediate country. The program decided that it was too risky to the individual and the schedule to pursue this option.

As the number of COVID cases rose in the UAE, there was a shift in philosophy regarding hotel accommodations. The team moved away from large multi-national hotels to smaller boutique hotels with different amenities. The staff at the larger hotels were very accommodating to our teams. The hotel was being constantly cleaned. The restaurants started to offer grab and go meals. However, given the government policies on COVID, the large hotels were only as strong as the weakest link. A single COVID positive test result, could result in everyone in that hotel being forced to quarantine. In the event that someone had to quarantine, they would be confined to their room 24x7 for up two weeks. The team chose to move to a different hotel that was much smaller, had balconies and windows that opened and had full kitchens. This transition reduced the likelihood of someone catching COVID or being caught in a lockdown situation. It also provided the team with an opportunity to get some fresh air when in their rooms.

With many rental car agencies operating at a reduced capacity, it became challenging to get cars for everyone traveling. This resulted in longer days for the team as people had to arrive earlier than necessary, or stay until others were done. Given the extended duration that people were on travel, the reduction in downtime and rest had an accumulative effect over the launch campaign.

From a personal logistics perspective, Dubai had a very mature food and amenity delivery infrastructure even before the onset of COVID. Numerous companies were available to collect and deliver anything that anyone needed. In contrast, there was limited “on-demand” infrastructure available on the small island of Tanegashima. Breakfast was the only hot meal available each day. Food was provided by a single kitchen with a boxed lunch and dinner provided for each person on travel. While the quality and quantity of food was excellent, the lack of choices over an extended period of time took some getting used to.

As the team continued to travel, more and more items were added to the essential items list. As an example: people started to take items with them that could turn their hotel room into a mini-gym. Things like yoga mats, elastic bands and push-up bars became standard items that were included in luggage when traveling.

## 5. Facilities

In the early days of the COVID pandemic, the transmissibility of the COVID-19 virus was not well known. It was clear that the virus was airborne, but it was not clear how easily it was transferred through physical contact. The reaction of many organizations at the time was to close the facilities and ask all staff to work remotely. LASP and the MBRSC followed this recommendation and locked down the facilities. Access lists were quickly formed to allow only essential personnel back on site.

The initial plan for reducing the risk of a COVID outbreak was to limit how many people were coming on site, and to coordinate schedules to reduce the likelihood of individuals being in the same work areas at the same time. Schedules would be created each week for when individuals would be in each room. These schedules were needed to allow for

critical activities that could not be performed from home and be safely executed. These schedules were also necessary to support an internal contact tracing system to alert individuals if they may have had a work place exposure to COVID.

The next area of focus was to try to reduce the likelihood of a work place transmission. Early in the pandemic, the MBRSC had greater success in procuring things like face masks, hand sanitizer and other cleaning products. LASP was able to work with suppliers to procure cleaning supplies. Unfortunately, the procurements were delivered in large bulk quantities which were challenging to use by individuals. LASP was able to create workspace cleaning kits for individual use. This resulted in a daily ritual where staff would check-out a cleaning kit when they arrived on site. They would then clean their planned work areas, and return the cleaning kit for the next person. At the end of the day, the ritual of cleaning would be repeated before people left for the day.

Special attention was given to areas where multiple people would need to work in the same room. On days of higher activity in these common work areas, cleaning kits were pre-staged. This made the cleaning process much more efficient. Plexiglass dividers were installed between workspaces, and the number of workspaces were reduced to allow the staff in the room to spread out more. Signs were posted to encourage people to move through rooms in a designated direction.

Changes were made to the facility air handling system at LASP. The air filters were upgraded from Minimum Efficiency Reporting Value (MERV) 8 to MERV 13. For comparison, MERV 8 filters will capture ~70% of particles between 3 and 10 microns and will struggle to remove particles less than 3 microns in size. A MERV 13 air filter will capture 90% of particles between 3 and 10 microns, and 85% of particles between 1 and 3 microns. Unfortunately, the COVID-19 virus is very small, on the order of 0.12 microns. However, in order to move large distances, the virus will often attach itself to a larger particle which could then captured by the air filters. In addition to added filtration, the facility air flow was reconfigured to use 100% outside air. Finally, room size High Efficiency Particulate Absorbing (HEPA) air purifiers were added to the operations rooms.

Finally, as more Personal Protective Equipment (PPE) became available to the general public, the facilities increased the requirements for facial coverings for on-site work. Initially this started with home-made masks, and then increased to a minimum requirement for a 3-ply disposable surgical mask. Due to limited supplies, N-95 masks were initially reserved for when people had to work within close proximity to each other for extended durations. Some facilities also required personnel to wear protective gloves and shoe covers while on site, and performed weekly on-site PCR testing.

## 6. Management

The COVID-19 pandemic created a number of challenges for the management team. Figuring out how to complete the final launch preparations and how to get people and things safely from point A to point B and then back home was extremely challenging. A key to our success was remaining nimble to the changes going on in the world around us and regular communication. The relationships and trust that had been nurtured from the concept development through final delivery allowed the team to assess the situation, discuss the potential option space, and pivot to a new plan in a very efficient manner. Decisions could be turned around in hours instead of days. The level of trust between staff, management and the stakeholders allowed the team to succeed in a challenging environment.

A key to this success was being focused on trying to stay ahead of the evolving travel restrictions. This allowed plans to be updated to avoid significant downtime with people or hardware stuck in some form of quarantine.

Finally, it was the ability of the senior management and government agencies within the UAE to collaborate with their counterparts in other countries to find solutions for the numerous challenges brought on by COVID. Through this logistically challenging time, they were able to find ways to get people and things safely where they needed to be to support the launch opportunity in July of 2020. There is a principle in the UAE that the Impossible Is Possible (Figure 6-1), that surely was true for EMM.


**Figure 6-1 UAE inspirational sign**

## 7. Conclusions

The journey from Dubai to Mars was an amazing accomplishment. In several cases the team significantly benefitted from decisions made early in the program to support remote collaboration and operations. These early fortuitous decisions made it possible for the program to shift from a facility-based operations concept to one that used a distributed support model. In other situations, it was the dedication of individuals that made critical progress day in and day out. Finally having a team that trusted each other allowed the management team to remain agile as it worked its way through the challenges created by the COVID-19 pandemic.

**Acknowledgements**

Many sacrifices were made in order to get Al Amal from Dubai to Mars orbit. It would not have happened without the support of a competent, experienced and dedicated team, working together to find solutions to every challenge. However, these people, no matter how hard they tried, could not have done it without the support of their families at home. We cannot thank them enough for their support. The EMM team would like to thank those who supported us during this challenging time to safely deliver Al Amal from Dubai to Mars.


**Figure 7-1 Al Amal image of Mars**