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Return to the Moon: A sustainable strategy

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Abstract

On 14 January 2004 President George Bush announced his vision for space exploration, to include a human return to the Moon. He argued that, with a moderate increase in NASA's annual expenditure, such a return was possible. This paper is an exploration of how the President's space initiative can be realised on an international co-operative basis along similar lines to those already existing with the international space station (ISS). By abandoning the concept of a lunar landing as the major goal of a lunar programme, the initiative is made feasible. The three-stage plan here presented meshes with the currently evolving plans for the US space initiative to provide a realistic, affordable and sustainable strategy for manned lunar exploration. It represents a significant opportunity for the USA to unite and lead the world on this grand, civilisation defining adventure.

1. Introduction

On 14 January 2004 President George Bush announced his vision for space exploration [1]. This vision included a manned return to the Moon. He argued that with a moderate increase in NASA's annual expenditure, a return to the Moon was possible. This paper is a big picture exploration of how the President's space initiative can be realised on an international co-operative basis along similar lines to those already existing with the international space station (ISS) and to do it within the budget he proposed.

It is ironic that a child born in the depths of the Great Depression in the 1930s was more likely to walk on the Moon than a child born at the height of prosperity in the 1960s. Why? To answer this simple question, it is important to recognise the reasons why the USA chose to go to the Moon in the 1960s and to draw from these the appropriate lessons to formulate a realistic, affordable and sustainable strategy for return.

1.1. The Apollo decision: is it a valid model?

Today, whenever space is discussed in public, the glory of Apollo is invoked to justify a return to a simpler and more heroic age. Comparisons with Apollo inevitably belittle any current effort and mislead decision makers into making false assumptions and comparisons. Political leaders inevitably fail the *''vision thing''* test and their programmes are killed off as being wholly inappropriate or not visionary enough. But is Apollo a fair and reasonable invocation? Did it further the manned exploration of space or did it stifle it? Can Apollo ever be a valid model for manned space exploration?

In May 1961 the USA felt humiliated. For years it had been humbled by a succession of Soviet space firsts shattering its image of scientific pre-eminence. On 12 April 1961 the USA saw itself beaten once again by the USSR when it launched the first man in space, Yuri Gagarin, into a single orbit of the Earth. Just 5 days later the country was further humiliated by the Bay of Pigs fiasco. To add insult to injury, just 2 weeks before President Kennedy's decisive May 25 speech to Congress, NASA launched its own first man in space, Alan Shepherd, on a suborbital flight which Soviet leader Khrushchev disparagingly described as a "flea hop". The shock of these humiliations filled the Kennedy administration and the Congress with resolve. The President and Congress were in the mood for an audacious plan to rescue their wounded national pride regardless of the financial cost.

In recently declassified White House tape recordings dating to 21 November 1962, Kennedy is heard telling the then NASA Administrator, James Webb [2,3]:

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> This is, whether we like it or not, a race. Everything we do [in space] ought to be tied into getting to the moon ahead of the Russians.
>
> I think it's good [to explore space], I think we ought to know about it, we're ready to spend reasonable amounts of money. But we're talking about 'fantastic' expenditures. We've wrecked our budget, and all the other domestic programs. And the only justification for it, in my opinion to do it [on this schedule] is because we hope to beat them, to demonstrate that starting behind, and we did, by a couple of years, by God, we passed them.
>
> [Beating the Russians to the Moon] is the top priority of the agency and … except for defence, the top priority of the United States government. Otherwise, we shouldn't be spending this kind of money, because I'm not that interested in space.

Clearly then, the circumstances that led to the Apollo decision were unique to their time. The decision to go to the Moon was not a romantic ideal to inspire a nation, but a hard-headed assessment of what was required to recover lost national prestige and political influence around the world [4,5]. It was driven by cold war realities in a campaign that saw both sides expend vast amounts of treasure in a headlong race to achieve pre-eminence in the political and technological spheres. The Moon race subverted all other more sustainable strategies for the manned exploration of space because it was never meant to be a long-term commitment. This is the fundamental point. Apollo was a political initiative; not a space exploration initiative. The Apollo program was perfectly adapted to its contemporary political environment, but as that environment changed it proved to be incapable of changing with it. Sadly, Apollo was a dead end.

Any attempt therefore, to use the Apollo decision as the model for a renewed strategy to return to the Moon is doomed. Such a flawed strategy will prove inadequate since the rationale and enormous expenditure will be inappropriate for a sustained and lasting effort. Moreover, in the present political climate, the vast expenditures will not be forthcoming. However, by adopting realistic and achievable goals based on the expenditure of more "reasonable amounts of money" a sustainable approach to manned space exploration is possible.

The vast cost of Apollo was due largely to the necessity of developing and constructing the entire infrastructure for the programme from scratch, and to do it quickly. If much of the infrastructure had existed beforehand, as it does today, and if it had been undertaken at a more sober rate, the cost of the programme would have been significantly less. One good lesson, however, can be drawn from the experience. Interest and support in the programme was sustained by the steady and visible progress of one successful mission after another. Political leaders and the public alike could see what they were getting for their investment, and they did not have to wait years to see it. Interest and support was sustained until the mission was finally accomplished, that is, the programme developed a momentum that saw it through to success.

1.2. The Soviet lunar effort

The USSR joined the Moon race late. This was partly because as the nation that was perceived to be leading the space race, the USSR was basking in the light of its success and so its leadership was not jolted into action as the USA was. When the race was joined, however, the Soviets were three years behind the Americans; a lead which ultimately proved to be too great [6–8].

In 1964 the Soviet Politburo authorised the expenditures to join the race and immediately trouble loomed. Because of the peculiarities of the Soviet system, there was no single authority to manage and guide the Soviet lunar effort. Instead, the effort to beat the Americans to the Moon was fractured by personal rivalries and jealousies amongst the heads of the competing design bureaus. This drained the precious and limited resources available and delayed crucial development. To make matters worse, the competing design bureaus could not agree on the method to reach the Moon. This eventually resulted in two competing programmes evolving separately, which further drained resources and introduced yet more delays.

The first programme was intended to bridge the gap in development and to catch-up with and beat the Americans to the Moon without the need to first develop a lunar lander and heavy launcher. The intention was to achieve a circumlunar flight using a pared down Soyuz, designated L1, but more commonly known in the West as Zond. This was to be launched to the Moon by a new medium-lift launcher, known as Proton, utilising a Block-D upper stage to boost it towards the Moon. The Zond would carry a single cosmonaut and perform a single loop around the Moon before returning to the Earth. This was a face saving programme that would allow the Soviets to claim they reached the Moon first. The first manned Zond flight was scheduled for early December 1968. But, as the launcher was readied on its pad, the mission was cancelled because technical problems with the Proton launcher could not be resolved before the launch window closed. Two weeks later, the launch window opened in the USA and Apollo 8 was launched. The success of the Apollo 8 lunar orbital flight spelled the end of the Zond programme since it paled in comparison to the more complex Apollo missions. The loss of face was deemed too great and the Soviets thereafter shifted their focus.

The second programme aimed for a human lunar landing and was to compete directly with Apollo. It involved the development of a giant new launcher, the N1, which was comparable to the American Saturn V. The N1 would launch a two-man crew with a lunar orbiter (an upgraded Soyuz, designated LOK) and a lander (designated LK) on a single flight. Once in lunar orbit, one crewman would transfer to the lander and descend to the surface to conduct an EVA before launching and returning to the orbiter. The programme suffered many setbacks with the N1 never achieving flight status. In 1969, just weeks before the Apollo 11 landing, an N1 on an all-up test flight failed seconds into its flight, completely destroying its launch pad. This disaster set the programme back more than 2 years. When eventually it was ready to fly again in 1971, the N1 failed once more just seconds into its flight. The problems with the giant launcher were never fully resolved and, after further flight failures, the programme was cancelled in March 1976. This ended the Soviet dream of landing a man on the Moon.

2. A logical approach

Ideally, a logical progression in the manned exploration of space would have involved the steady development of capabilities, building one on top of the other. This would have progressed from initial manned orbital flights to the construction of a space station with a space shuttle to ferry crews and resources back and forth. Eventually, manned flights to the Moon and beyond would have been attempted as a natural progression building on existing hardware and infrastructure. This approach was popularised by Wernher von Braun in his series of 1952 *Collier's* magazine articles. Remarkably to this day, his plans have remained essentially unchanged as the model for the manned exploration of space [4].

The space race and Apollo delayed the introduction of this logical sequence by leap-frogging the necessary earlier stages in this development. Consequently, in an effort to regain a sense of direction after Apollo, the American manned space programme floundered and progressed in an often inefficient manner. Programmes were started and finished sometimes without so much as a single flight being undertaken, while others failed to meet their original optimistic objectives. In short, in an effort to maintain its pre-eminent position in space, the US manned space programme was driven by concerns not related to a natural progression of capabilities.

On the other hand, once the USSR abandoned its efforts to beat the USA to the Moon, it returned to this logical progression and methodically developed its capabilities. It first achieved regular and reliable access to space with its Soyuz series of spacecraft. It then developed its Salyut space stations with increasing size and complexity as destinations for its crews. This led to progressively longer stays in space until, with *Mir*, it achieved a continuous presence in space for an astonishing 15 years. All along, it continued to develop and advance its tried and tested technology. Today, much of this technology is the basis of the ISS and sustains its current operations. In fact, with the grounding of the Space Shuttle programme following the *Columbia* accident in 2003, the ISS is critically dependent upon it and will continue to be for some time to come. The success of this approach is self-evident and it should form the basis of an affordable and sustainable strategy for manned space exploration.

2.1. Current capabilities

It is interesting to note that the Soviet and Russian manned space programmes of the past 35 years have been largely based on the abandoned Soviet circumlunar programme. Unlike Apollo, which saw the US dismantle almost its entire lunar infrastructure, the Soviets maintained and advanced theirs without realising it. In other words, the essence of the circumlunar programme has been maintained without actually conducting a lunar flight.

The Proton launcher, which was originally developed to launch the Zonds toward the Moon, has been developed and advanced to the point that it is now a very reliable medium lift launch vehicle. The Proton has been regularly used to launch the various Salyut, Mir and ISS modules as well as various other Soviet planetary space probes. In its latest variant, the Proton M, it is now even offered to commercial customers as a competitor to Western launch vehicles, and it continues to be developed and enhanced with more efficient engines and heavier lift capability. It will continue to be active and competitive for some time to come [9].

In addition to the Proton, several versions of the Soyuz have been developed over the years that have improved on its capability and reliability, with the latest variant being the Soyuz-TMA. It has been the workhorse of the Soviet and Russian manned space programmes for over 35 years. Its safety and reliability are recognised to the extent that the USA has recently called on its services to ferry its own astronauts and crews to the ISS. The original Zond (L1) lunar craft was a pared down derivative of the basic Soyuz design. Another derivative of the Soyuz has been employed as the unmanned Progress ferry craft for resupplying the manned orbital platforms for over two decades. It too continues to be developed and advanced and is currently being used to resupply the ISS [9].

Essentially therefore, the Russians today are in a position to fly a Zond-type circumlunar mission if they so choose. In fact, Russia is the only nation remotely capable of undertaking such a mission at this time. This is a marked turnaround from three decades ago.

After abandoning their lunar programme, the Soviets advanced in small incremental steps rather than in dramatic giant leaps. Building on, and utilising, existing hardware as much as possible was deemed essential. The Soviet Energia/*Buran* space shuttle was the exception and precisely because of that it failed. It was driven by a political desire to match the USA, rather than by practical necessity. As demonstrated by the Soviet and Russian successes, the small step approach is ultimately more reliable and sustainable than the giant leap approach and should be the model for an affordable path to human space exploration.

What is required therefore, to undertake a manned lunar mission today? Can it be made affordable and hence sustainable over the long term and within the budget proposed by President Bush?

3. The plan—building a capability

The ISS is today assailed by many critics for being a structure in search of a mission. The ISS was planned and constructed to realise the long-held dream of a permanent manned presence in space. An early selling point to Congress was that it could be exploited for industrial and medical applications. Unfortunately, these plans did not materialise because they were not economically viable. In fact, until its construction is completed, the full potential of the ISS to conduct useful microgravity research in life and physical sciences will not be met [10]. Beyond completing its construction and providing a permanent manned presence in space, there is currently little to justify the enormous cost of building and maintaining it. Already, there are calls from many in Congress, and from within NASA itself, to abandon the ISS once its construction is completed in order to help finance the President's space initiative. This is not surprising because it is precisely what happened to Apollo. Once the objective was met, the reason for continuing no longer existed. Why won't this same fate befall the space initiative? The trick is to avoid a programme with a specific goal, but instead to work on establishing a capability that can be called on to achieve specific tasks when the needs arise. In order to avoid a boom and bust cycle, the capabilities developed will need to be made affordable by building on existing infrastructure, in incremental steps.

Fundamental geopolitics provided Apollo with the compelling reason to land on the Moon. Today however, no such compelling reason exists beyond the inspiration provided by such a grand adventure. This situation may change in the future, but until then it is critically important to approach the space initiative in a realistic and affordable manner.

3.1. Redefining the mission

The most dangerous, complex and expensive part of any manned lunar programme is the lunar landing. However, by abandoning the concept of a manned lunar landing as the primary goal of a lunar programme, it suddenly becomes affordable. A manned lunar programme should instead concentrate on developing and perfecting operations in lunar orbit. A lunar station can be developed to act as a destination and objective for these orbital operations. Lunar landings could then be performed as occasional extensions to this programme and not as the ultimate goal. This plan leaves open the prospect of eventually establishing a permanent presence on the lunar surface when compelling reasons arise and not before. By getting the programme moving with rapid and achievable goals we can find ourselves in a position to pursue these more ambitious goals when required. Such an approach will lead to a sustainable, affordable and ultimately more beneficial outcome. How is this to be achieved?

A three-stage approach is proposed. By beginning with small incremental steps, and by utilising existing hardware and infrastructure as much as possible, the programme can begin and be moved along quickly. This three-stage plan meshes with the current plans for the proposed US space initiative to get the programme underway quickly while political support still exists.

Phase 1 in the plan will involve initial lunar flights to demonstrate the utility of the existing hardware and techniques. Phase 2 will involve the establishment of a lunar station to act as a destination for lunar flights. During this phase, more advanced vehicles will be developed that will eventually become the foundation of long-term sustainability of the programme. Phase 3 will see the programme extended to include occasional manned lunar landings.

3.1.1. Phase 1

The first phase of the plan should be viewed as the equivalent of the Gemini flights of the pre-Apollo era. While the main Apollo programme was being planned and established, the Gemini missions of the mid-1960s enabled NASA to move the programme along by using existing hardware and infrastructure to test the techniques required to fly an Apollo mission to the Moon. These Gemini missions were spectacularly successful and ensured the ultimate success of Apollo. The President's space initiative will take many years to plan and establish. It is essential therefore, to move the programme along before the political support for it evaporates.

The programme must begin quickly with tangible and visible results achieved at reasonable cost. A circumlunar flight meets these criteria and should be the first objective of the programme. This is a straightforward flight which can be accomplished quickly and at relatively little expense. Such a mission would kick-start the programme and give it valuable momentum. It would energise the imaginations of the public and political leaders alike and would encourage continued support. Critics will argue that this is significantly less than an Apollo flight, a stunt in fact, and that it would represent a backward step. However, since we are not in a position to undertake Apollo-like missions, a realistic strategy must be sought. A circumlunar flight is a necessary first small step to prove the men and machines.

In this first phase all the essential elements for a modern circumlunar flight either exist today or can be relatively easily modified and developed from existing hardware and infrastructure. A modern Soyuz vehicle can be modified to act as a manned circumlunar spacecraft as in the original Zond. It would be launched by a single Proton launcher. It would be boosted into a free-return, lunar trajectory by an insertion stage which can be designed and developed from existing modern rocket engines. The craft would loop around the Moon before re-entering the Earth's atmosphere after a 5–6 day flight.

The cost of such a mission is relatively low. Conceivably, at a cost of no more than US$1 billion, the insertion stage can be developed from existing modern rocket engines in as little as two years. This is an essential piece of hardware that can be used time and again on all future lunar missions. It should therefore be the first item developed in the programme. For possibly another US$1 billion at most, the current Soyuz and Proton elements can be modified for a manned circumlunar flight. This flight can be used to test the insertion stage, and will give the programme its first imagination grabbing success. Hence, in as little as two years from the initial go ahead of the programme, a piloted lunar flight can be realised for no more than US$2 billion—well within the budget proposed for the President's space initiative.

On more ambitious, subsequent flights the insertion stage can be used to insert the craft into lunar orbit and then inject it back again into a trans-Earth trajectory. The entire configuration should be capable of sustaining regular and affordable manned missions to lunar orbit.

3.1.2. Phase 2

The second phase of the programme builds on these initial successes and advances the programme with more ambitious missions and equipment, eventually leading to a continuous presence in lunar orbit.

As a way of providing a destination and objective for lunar missions, modules using existing ISS designs to save costs can be modified and placed into lunar orbit to act as a lunar station. This lunar station need not be as grand and large a structure as the current ISS—it only needs to provide a destination and living space for a few weeks at a time. The lunar Soyuz would dock with the lunar station to provide for extended stays in lunar orbit. From this orbit, the lunar surface can be studied with an array of instruments. Valuable experience can be gained in operating and living in lunar orbit.

A variant of the Progress ferry craft can resupply the lunar station by using the insertion stage. Since these ferry craft are robotic, they need not be launched into fast lunar transfer orbits—they can utilise more fuel-efficient, slower transfer orbits to traverse cislunar space.

While the initial cislunar operations are being undertaken a new, more advanced lunar orbiter can be developed to eventually replace the lunar Soyuz. This development can proceed over a long lead time to save on costs and lessen the impact on annual budgets. The advanced lunar orbiter will have larger crews and will be capable of undertaking more ambitious and longer duration missions. It too will use the insertion stage to boost it toward the Moon.

3.1.3. Phase 3

Meanwhile, as experience is gained in living and operating safely and efficiently in lunar orbit, a manned lunar landing vehicle can be developed. Since manned lunar surface operations are not the primary goal of such a programme, the development of a manned lunar lander can be extended over an even longer development time than the advanced lunar orbiter to further reduce costs and lessen the budgetary impact.

Once developed and built however, the lunar lander can be launched without a crew and docked to the lunar station by again utilising the insertion stage and the same fuel efficient transfer orbits as used by the resupply vehicles. Once docked to the lunar station, the lander can be checked out and prepared for a human descent to the lunar surface at a convenient time.

The initial manned lunar surface operations would only extend for a maximum of 2 weeks—essentially for the period of one lunar day. Operations longer than this would not be useful since operating during the 2 weeks of the cold lunar night would add to the hazard and greatly increase the costs and complexity of the mission. The only justification for operating on the lunar surface, at least for the foreseeable future, is to conduct geological surveys [11,12]. There is only so much geology one can do at a particular site before you need to move on again. Vague objectives of exploiting the mineral wealth of the Moon and mining He-3 are simply not economically viable at the present. In fact, manned lunar surface excursions should be the exception rather than the rule for any lunar programme. There are several reasons for this.

First, without the need constantly to land and resupply a manned lunar base, the costs of the lunar programme are greatly reduced. Second, robotic rovers could more easily and affordably land and study the surface. These robots can be controlled from the lunar station with operations conducted on the lunar far side just as easily as the near side. Only when a site of exceptional scientific interest is identified will a manned landing be attempted with a very specific targeting of objectives. Finally, since there is no need to conduct these manned landings on a routine basis, they can be scheduled to occur at irregular and widely spaced intervals thus further reducing the costs in both development and construction. In this way, the lunar landings become extensions to the lunar programme rather than the rationale for it. This strategy enables manned lunar landings to be realised without the exorbitant costs associated with such a programme, thus ensuring its long-term sustainability. This strategy leaves open the prospect of eventually establishing a permanent presence on the lunar surface by providing the capability to pursue more advanced surface operations when compelling reasons arise in the future. These operations also provide a model for conducting the manned exploration of Mars, albeit with far different machines.

3.1.4. Storm shelters

Astronauts on extended lunar missions will be vulnerable to solar particle events (solar flares) in a way that astronauts in low-Earth orbit within the Earth's magnetosphere are not. Some thought would need to be given to radiation protection, perhaps providing a shielded module, attached to the lunar station, to act as a "storm shelter". Indeed, protection from solar storms would be greater in lunar orbit than on the lunar surface. In orbit, the astronauts would be protected for roughly half the orbital period by the shear bulk of the Moon itself, thus allowing them to operate during the orbital night-time periods. By contrast, astronauts conducting lunar surface operations would be exposed to the radiation continuously. Landing a heavily shielded (and massive) storm shelter, or covering the base with metres-thick layers of abrasive lunar regolith would just add to the expense and complexity of the landing missions. Better to leave these until much later when they are more affordable.

3.2. The ISS role

The ISS can be used as a staging post to assemble, prepare and launch the resupply ferry craft as well as the lunar station modules and lunar landers. Since these vehicles will be robotic, they will not require fast and efficient flights to the Moon, so they can be launched to the Moon from the ISS on the slow transfer orbits which are possible from the high inclination orbit of the ISS. This scenario will give the ISS a useful mission objective and justify its existence.

In addition, as an alternative to direct ascent flights to the Moon, the various segments of the proposed manned programme can first be assembled at the ISS, before being sent on to the Moon. This Earth orbit rendezvous (EOR) technique will alleviate the need to develop heavy launchers for any future missions by utilising multiple launchings of the existing medium lift boosters instead, thus saving on the significant development costs still further.

The high inclination orbit of the ISS makes such flights highly fuel-inefficient because of the large orbital plane change that is required to go from the ISS to the Moon. None-the-less, they are possible, especially when short flight times are not essential as with the robotic flights.

Eventually, all cislunar operations could proceed in the same regular and routine fashion as the current low-Earth orbit operations. The proposed phase 1 manned lunar missions can be viewed as an extension to the current ISS operations. These missions will differ only in their choice of launch vehicles and trans-lunar orbits. In fact, viewed in this way, by employing the current ISS and Soyuz vehicles and utilising the EOR technique, we currently have a lunar programme—we only have to fly it!

3.3. Mars and beyond?

Continuing on to Mars is the ultimate goal of the proposed US space initiative and the same strategies for the lunar programme can be employed to further extend the human presence in the Solar System. However, because Mars requires such a quantum leap in capability and cost, attempting such missions in the foreseeable future will result in a repeat of the Apollo decision and the leap-frogging of essential first steps in development. This will subvert the logical and sustainable progression with no guarantee of success. Costs will inevitably blow out and will make any future long-term strategy even less likely to be initiated. It should therefore, proceed only when lunar operations are perfected and when progressing on to Mars becomes the next natural step in capability.

3.4. The timeline

The timeline for the plan is illustrated by Table 1. Assuming a start date of 2006, the following 2 years would be spent developing the insertion stage and modifying the Soyuz and Proton for lunar flights. Then just 2 years after the go-ahead for the programme was given, the complex could be launched on the first manned circumlunar flight. The long-held dream of returning to the Moon would be realised.

The next 3 years would then see lunar orbital flights being attempted and perfected with this flight configuration. Meanwhile, a lunar station could be established using existing ISS module designs. These ISS station modules can be suitably modified and placed in lunar orbit six years after the go-ahead is given. Once there, the station will act as a destination for all future missions.

Running concurrently with the station development, the Progress resupply ferry would be modified in order to resupply the lunar station. Such modifications will be relatively minor, essentially giving it more fuel for manoeuvring and enhanced guidance capability. Integration with the insertion stage will have already been developed with the lunar Soyuz. The first flight of the Progress can then be undertaken soon after the first crew arrives to man the lunar station.

While these developments are being undertaken, the advanced lunar orbiter would be developed. This orbiter would eventually supersede the lunar Soyuz and would

Table 1
Timeline for the strategy

Development time	Item
	Phase 1
2006–2008	Insertion stage development
2006–2008	Lunar soyuz modifications
2006–2008	Lunar proton modifications
2008	First circumlunar flight
2009–2012	Initial lunar orbital flights
	Phase 2
2006–2012	Lunar station development
2008–2012	Lunar progress modifications
2008–2015	Advanced lunar orbiter development
2012	Lunar station placement flight
2012–2015	Lunar soyuz flights to lunar station
2012	Initial lunar progress flight
2015	Initial advanced lunar orbiter flight
	Phase 3
2010–2020	Lunar lander development
>2020	Occasional manned lunar landings

become the workhorse for the programme for many decades. Meanwhile also, a lunar lander would be developed over an even longer development time. This lander would permit stays of up to 2 weeks on the lunar surface. However, since the surface operations are not the ultimate objective of the programme, but simply extensions to it, these operations would be highly targeted with very specific goals.

This programme builds a strong, affordable and thereby sustainable foundation on which to build all future dreams of exploration.

The ISS and the Soviet and Russian space programmes of the past three and a half decades can be viewed as the steady establishment of a space capability which can be called on to advance humanity's presence in space beyond low Earth orbit. By building on this, the logical progression of capabilities, first enunciated by Wernher von Braun over half a century earlier, will have been realised by a circuitous route.

4. A cooperative approach

In 2003, China became only the third nation to launch a man into space [13]. The Chinese taikonaut, Lt. Col. Yang Liwei, was launched atop a Long March 2F booster. The design of the Chinese orbiter, Shenzhou 5, was based on the Russian Soyuz and bears a remarkable resemblance to it. Shortly before the 14-orbit flight of the Shenzhou, the Chinese president remarked that the ultimate goal of the Chinese space programme was a manned lunar flight. There is no doubt, that with the Shenzhou orbiter the Chinese have built a capability to fly a Zond-type circumlunar mission. They only lack a large booster to undertake such a mission by direct ascent, that is, on a single launch. However, by employing an EOR technique and docking to an insertion stage previously launched, it is possible to fly the lunar mission without the need to develop a costly larger booster. This can be done in a relatively short time if China so decides, especially if it cooperates with a second nation like Russia.

Meanwhile, India has been steadily developing its space capabilities with the stated objective of eventually achieving human flights in Earth orbit and beyond. In January 2003, at an educational conference in Mumbai, the Indian Prime Minister, Atal Behari Vajpayee, remarked that Indian scientists should work towards sending a man to the Moon as the ultimate goal of its space activities. In addition, Europe and Japan are developing plans to explore the Moon with robotic spacecraft. Their distant aim is eventually to fly manned lunar missions either by going it alone or in cooperation with other space powers.

It is clear that President Bush's announcement of a return to the Moon and beyond was in response to these developments. The marriage of capability and political will is coming together once again as it did for the Apollo decision. But what form will it take this time and is it sustainable?

As is obvious, the plan outlined above for a sustainable return to the Moon, is dependent on Russian cooperation in the early stages of the plan. This is not a radically new idea. The ISS is now largely a cooperative undertaking between the USA and Russia. Both American and Russian designed and built space station modules were launched by the Space Shuttle and Proton booster. The original ISS module, Zarya, was based on a module originally designed for the proposed Russian *Mir* replacement station and was launched by Proton to act as the core of the ISS. Following the *Columbia* accident, the ISS is now sustained by regular and routine Soyuz and Progress flights to staff and supply the station. In addition, the Europeans, Japanese and Canadians have plans to participate more fully in the ISS by adding their own modules. Clearly then, the ISS has demonstrated the value of the cooperative approach, without which it would never have been realised. By using modifications to the same hardware and infrastructure, the lunar programme outlined above can be modelled on the ISS operations and become an extension to it.

4.1. US leadership

Section 6 of the 'Iran Nonproliferation Act of 2000' (INA) [14], forbids the US from purchasing or securing Russian space services not directly related to the previously agreed commitment to the ISS. The only exceptions are for crew safety to prevent imminent loss of life or grievous injury to personnel on board the ISS (Sec. 6(f)), and for maintenance activities which cannot be performed by NASA, as was the case with the Space Shuttle grounding following the 2003 *Columbia* accident (Sec. 6(g-2)).

US plans for the new space initiative are still evolving, but all are based on the development of a versatile new crew exploration vehicle (CEV) that will permit manned flights to low Earth orbit (LEO) and beyond. In terms of its access to space, a new heavy-lift launch vehicle will be required and may be based on a Shuttle heavy-lift derivative, a modification to one of the new Evolved Expendable Launch Vehicles (Delta IV or Atlas V), or an entirely new launch vehicle. In addition, a manned lunar lander will be developed concurrently. This plan is beginning to look increasingly like Apollo.

Regardless of the eventual form of the plan, it is clear that the proposed space initiative, involving the development of three new advanced vehicles, will be extremely expensive and will take many years to develop. There is no certainty of the political will persisting long enough to see the first CEV flown, let alone achieving a lunar flight. In the current fiscal climate, the programme could be cancelled before the first tangible results are seen. The moderate increase in NASA's annual budget, intended to finance this programme, is simply not sufficient for this ambitious plan to be realised in a reasonable time. It runs the risk of interest being lost in the programme, reminiscent of the Space Station *Freedom* debacle.

In contrast to this, the proposed cooperative plan outlined above is modest. With the development of a single, new insertion stage and the modification of existing vehicles, a first lunar flight can be achieved in just two short years. The first tangible results will be clearly evident, giving the programme valuable momentum and continued public and political support. By treating the phase 1 operations as the equivalent of the pre-Apollo, Gemini programme, where hardware and techniques are tested with existing and modified equipment, results can be achieved rapidly, while developing the "real" programme over a longer development time. In this way, public interest and support can be maintained over the long haul. By seizing the initiative, the USA has an opportunity to lead the world in this co-operative endeavour.

The first step of the programme (and the least expensive part) is to amend the INA in order to permit the use of Russian hardware in the phase 1 operations. This is not as great a political problem as it first appears, since, with the cut back in the proposed number of Space Shuttle flights and their eventual retirement in 2010, the Bush Administration and NASA are already proposing to decouple the use of Russian hardware from the INA. This is deemed essential in order to provide a continuous access to space to complete the construction of the ISS and to service it until the first CEV flight is undertaken sometime around 2015. There is growing support in Congress for this amendment [16].

Once the INA is amended, the CEV can then be re-developed as the Advanced Lunar Orbiter to supersede the lunar Soyuz. Each nation can be assigned to develop a specific aspect of the programme. Further agreements can be struck that allow several nations to participate, with the USA taking the clear lead. By sharing the hardware and the cost, the dream becomes affordable, sustainable and doable, just like the ISS.

The USA could choose to go it alone, however. By abandoning the phase 1 stage of the programme and adopting the phase 2 and 3 stages only, it can wait until it develops its CEV and new rocket boosters to implement the President's vision independently. By doing so, however, it risks losing time and political support. The whole point of the phase 1 stage is to kick-start the programme and achieve impressive results quickly, thus ensuring continued political and public support. Kennedy chose to go to the Moon because it offered the USA an even start. With Russia's capabilities to perform a circumlunar flight if it so chooses, and the rest of the world's developing capability and willingness to conduct such manned lunar missions, the USA no longer enjoys this luxury.

On the other hand, US leadership in this cooperative enterprise will be a welcome tonic. In today's world political climate, how inspiring it would be for the USA to unite and lead the world on this grand, civilisation defining adventure. In just two short years, astronauts can begin the process of living and working routinely in lunar orbit and all for a minimal budget of just a few billion dollars a year.

5. Conclusion

The tragedy of manned lunar exploration was not that the USA gave up on Apollo; the tragedy was that the USSR abandoned its efforts. It would have been inconceivable for the USA to surrender its stewardship of the Moon if the Soviet Union had flown so much as a single circumlunar flight, let alone achieved a lunar landing. If the USA fails to engage in this great adventure, other nations, notably Russia and China, and possibly even India and Europe, are quite capable of going it alone. The USA will lose its stewardship of the Moon. Like Aesop's hare, it will have a rude awakening. Playing catch-up will be even more expensive.

With the grounding of the Space Shuttle programme the ISS has been efficiently and routinely sustained by the Soyuz and Progress vehicles. Indeed, the proposed lunar programme can be modelled as an extension to the current, cooperative, ISS operations. With a few relatively minor modifications and with the use of the EOR technique, we currently have a lunar programme—we only have to fly it!

As evidenced by Kennedy's remark in 1962, governments do think that the exploration of space is a good and worthwhile thing to do, but provided it is done at reasonable cost. The United States has an opportunity to unite and lead the world in this grand adventure.

The inspiration of Apollo was that it succeeded and hence elevated mankind. The lesson of Apollo is that the big projects ultimately fail because they are unsustainable. To make them sustainable they must be made affordable. This is achieved by using as much existing infrastructure as possible and advancing soberly in incremental steps. By abandoning the concept of a manned lunar landing as the primary goal of a lunar programme, the programme is made affordable while leaving open the possibility for more advanced excursions on the lunar surface when the needs arise. The first flight can be achieved in just two short years—before the end of President George Bush's second term.

Over the past three and a half decades, a space capability has been developed such that advancing beyond low Earth orbit and progressing on to the Moon becomes an achievable and affordable natural progression if we choose to use it.

Apollo was a *tour de force*, but like the mythical god, it blazed across the sky for a short time before its flame was extinguished. It is now time for a new dawn, a new beginning, one with a more lasting legacy. It is time to stop dreaming and get on with it!

5.1. Postscript: recent critical developments

Following the initial submission of this paper, a number of critical developments have occurred, that impinge directly on the arguments and ideas proposed in this plan.

On 26 July 2005, just as the Space Shuttle *Discovery* was launched on its return to flight mission, the Russian Space

Agency, Roskosmos, and the Russian aerospace company, Energia, announced plans to fly a Soyuz mission to the Moon within 2 years. In concert with the American company, Space Adventures Ltd, the plan involves sending a paying space tourist on a 2 week circumlunar flight. A cosmonaut and tourist will spend a week at the ISS before docking with an accelerator block (designated Block DM), launched separately to the ISS by a Proton booster. The accelerator block will then inject the spacecraft on a free return trajectory toward the Moon, passing just 100 km above the lunar far side. The price tag of the tourist ticket is US$100 million. This cost includes the development of the accelerator block and its launch on a Proton booster. A test flight involving an unmanned Progress vehicle to demonstrate the concept is also included. Russian space officials believe that just 18–24 months is required to build and fly the hardware on the mission. Space Adventures has already sent space tourists to the ISS for a reputed US$20 million each. Even if the stated price tag of US$100 million is US overly optimistic and underestimates the cost by as much as an order of magnitude, it still represents an achievable and affordable capability. This EOR plan, utilising the ISS and existing Soyuz and Proton vehicles with the added development of an insertion stage, is identical to the proposed phase 1 operations independently outlined above. Clearly then, the Russians are already thinking along these lines and are aware of their own capabilities. They are willing and able to fly the mission in the time proposed.

On 16 September 2005 NASA unveiled its long awaited Exploration Space Architecture Study (ESAS) which outlined its plans for a return to the Moon by 2018 [17,18]. Briefly, this new exploration architecture is essentially a beefed-up version of Apollo, which Administrator Michael Griffin succinctly described as "Apollo on steroids". The new mission profile is not new and is in fact based in large part on early Apollo mission profiles conceived in the early 1960s. It would see the development of two new launchers rather than one. It would employ a combination of the EOR and lunar orbit rendezvous (LOR) techniques of the original Apollo plans of four decades ago. The only major departure from the Apollo plans would be the use of liquid methane propellants in the CEV service module engine and in the ascent stage of the lunar lander. The two new launchers would be based on Shuttle derived elements to save costs. The first booster, the crew launch vehicle (CLV), would launch the CEV into Earth orbit. The second booster, the heavy lift vehicle (HLV), would launch the lunar lander and the insertion stage. They will rendezvous with the CEV in Earth orbit before the entire assembly is injected into a trans-lunar trajectory. The CEV and the lunar lander bear a striking resemblance to their Apollo era counterparts—only bigger. The budget for the plan is estimated at US$104 billion spread over 13 years. However, even before the plan was released, storm clouds began appearing on the horizon. Hurricanes Katrina and Rita devastated large parts of Louisiana and other Gulf States in August and September 2005, causing enormous damage and leaving behind a potential rebuilding cost of over US$200 billion. Combined with the ongoing costs of the Iraq war, Congress may yet baulk at the large price tag of the programme and may redirect funds away from the space initiative to pay for the rebuilding of the storm damaged economies and for the war. This will inevitably delay the programme with the consequent loss of political support being more likely. The first Moon landing in this plan will not occur for another 13 years at the earliest. This means that as many as three separate US Administrations (and possibly more) will need to support the plan before the first lunar mission is accomplished. With this in mind, the arguments stated above against an Apollo-like programme are still valid.

On 26 October 2005, the 'Iran Nonproliferation Amendments Act of 2005' was passed by the US Congress [15]. Specifically, the relevant part of the act is Section 3 relating to ISS payments. This section permits the purchase of Russian space hardware "prior to 1 January 2012, for work to be performed or services to be rendered prior to that date necessary to meet United States obligations under the Agreement Concerning Cooperation on the Civil International Space Station". The amendment was necessary since under a 1996 "Balance Agreement" between NASA and the Russian space agency, Russia was obligated to provide 11 Soyuz vehicles for crew rotation of US and Russian crews. The last of those 11 Soyuz vehicles was launched in October 2005, and was scheduled to return to Earth in April 2006. After that, Russia would no longer allocate any of the seats on its Soyuz spacecraft for US astronauts. Russian space officials had repeatedly indicated that they would not provide crew return services to NASA gratis once their obligations were fulfilled under the Balance Agreement [19]. Although this amendment relates specifically to the ISS, and does not decouple the use of Russian hardware from the INA, it does however augur well and demonstrates that the INA could be amended to allow the use of Russian space hardware in the proposed phase 1 lunar operations outlined above.

On 12 October 2005 China successfully launched its second manned space flight aboard the Shenzhou 6. The two taikonauts, Fei Junlong and Nie Haisheng orbited the Earth for 5 days. Following the successful completion of the mission, plans were quickly revealed for future Chinese ventures in space. These included EVA's, space dockings and the establishment of a space station. In early November 2005 both the Roskosmos chief, Anatoly Perminov, and his deputy, Yuri Nosenko, indicated that Russia could help China implement its lunar research programme, culminating perhaps with a manned lunar mission. This was confirmed on 27 November 2005, when Hu Shixiang, deputy commander-in-chief of China's manned space flight programme, said during a tour of Hong Kong that in 10–15 years time China hoped to have the ability to build its own space station and to conduct a manned lunar landing. The goal was subject to full funding, Hu said, and must fit within the larger scheme of the country's overall development.

These developments indicate that a manned lunar programme is an idea whose time has come. Whether it will be another false dawn, as with Apollo, or whether it will have a more lasting legacy, will depend on the strategies adopted. The proposed lunar programme outlined in this paper provides a sustainable and affordable way forward.

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