Some Thoughts on the Columbia Disaster and how to proceed from here

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INTRODUCTION.

Much has been said in the past few days and will be said in the weeks to come – about the promise and costs of the Space Shuttle and the promise and costs of Space Enterprise. It is sad that it takes tragedy to focus our affluent and overindulgent society on the core issues of human enterprise and of the core importance of Space to America's future – in Space and on Earth. The "sacrifice" of the Columbia disaster may well turn out to be the pivotal event to renew the United States commitment to Manned Space Exploration and Enterprise.

First a historical note: 2003 will also see the launch to and return from Space of the first astronaut launched by China. Without "Columbia" we might have seen – and still might see – a true reversal of roles at the junctions of history. In the 15th century China was the world's leading, dominant nation, the "center" of the world and the world's leading ship building nation as well. Chinese voyagers set out to the shores throughout Asia Pacific, of Africa and, were one to believe recent speculations by British investigators, even the Americas and through the straights of Magellan to a round trip back to Asia. Just as the circumnavigation of Africa (and accidental side trips to the shores of South America under Pharaoh Necho 600 B.C. these tales of enterprise largely go untold. In the 15th century the future of mankind was for China to take, but it was Europe who set out to indeed do so. The reason for China's abject failure: some quirk in the succession of emperors and empresses and the sway of eunuchs when empresses reigned these bean-counters of ages past asked the "obvious" question: why spend all this treasure to visit barbarians and wastelands at the rims of civilization – if these barbarians and other lowlife are interested let them come to visit us at their expense, so to say the Charles Krugman in Chinese 15th century cloth. As they say, the rest is history: Europe brought Christianity and civilization to the rest of mankind in centuries to follow.

We are today at a frighteningly similar junction, with bean-counters and administrators running our government affairs and "intellectuals" writing away in all their brilliance of the benefits of static income redistribution from the "rich" to the "poor". Had we followed their advice in eons past we would be still sitting in the caves of Africa and Afghanistan, redistributing the catch of the day from those successful in the hunt when venturing out - and stupid enough to return - to those who stayed home in their caves.

But in addition to this overriding rational for Space Enterprise and the Space Shuttle, there were and are also strict utilitarian (economic) reasons for the Space Shuttle and Space Enterprise. Since I was in charge of the independent assessment effort of the Space Transportation System directed by the White House for NASA in 1970 through 1972 let me share with the readers the rational put forth then and – equally important – how that compares to the "facts" thirty years later. My conclusion: we were right down to the last digit and sentence I

our assessment then – with not one iota to change – and we could be right today again – as long as we persist in this enterprise – of reusable vehicle(s) access to space and manned Space enterprise beyond. I will outline first the cost-efficiency case made in 1971 – combined with my analysis of what really (and obviously to some extend) went wrong) along this journey and then proceed in Part II to the promise of Space we saw in 1971 – and still see today. Based on this I will also point out the need for a clear, single goal for manned Space flight – and venture to state that goal.

I: THE RATIONALE FOR THE SPACE SHUTTLE DECISION IN 1971.

Contrary to perceptions, in no small part bandied about even by NASA bureaucrats, the case for the Space Shuttle - and by the way integrally also for the Space Tug for a full reusable Space transportation capabilities to all Earth orbits – **was NOT build on transportation cost savings**: any and all presentations made by us on this issue start out: the Space Shuttle can NOT be justified solely with the narrow argument of transportation cost savings. Indeed it is this statement and the logical exposition of the REAL case for the Shuttle that won me the award to do the independent outside assessment by NASA in 1970 to begin with. Imagine: a $3 million contract, limited explicitly to five pages of substantive exposition AND a full day cross-examination as to the rational AND to start out the presentation with the statement: “The reusable Space Transportation System (Space Shuttle and Space Tug) can NOT be justified on transportation costs!”

After the cross examination was over (a Tuesday of a full week of competing proposals), I knew my team had won – the contract and the logic for the Shuttle and Tug: the program would be approved, a new age would be opened for the United States in Space Exploration and Enterprise!

So what WAS the logic for having a Space Shuttle and Tug – other than manned Space flight?

1. First: Space Transportation Costs.

The very first Table in the Executive Summary as well as in the Main Report by us to NASA clearly and simply stated that New Expendable (rocket) systems would be cheaper in terms of life cycle costs: some $11 billion for New Expendables vs. $12 billion plus some for Space Shuttle and Tug. All this NOT including manned Space flight missions!

However one “massaged” the NASA and DoD mission models (we reduced the mission numbers given to us by the agencies by up to 67%) there was no way to “justify” the Space Shuttle based on transportation costs over a 10 year, 20 year or even “infinite” time horizon – where “infinity” has a way of shrinking drastically when reasonable discount costs are applied to “future” savings, which we did.

2. **"Payload Effects":** whereas transportation costs were at best a "draw" the real reason for reusable Space Transportation capabilities – to Low Earth Orbit (LEO) and higher Earth Orbits all the way up to Geo-synchronous orbits for stationary communications satellites) and beyond, ideally including Lunar orbits as well, the payoff of these novel capabilities is in the vast effect these capabilities would (will) have on the very conduct of Space missions, their reliability and capabilities. This is what we stated then and what we mean by these effects:

   2.1. The ability to revisit any and all satellites in Earth orbit will allow for the **maintenance, repair and updating** of these instruments and spacecraft. Transportation costs constitute only one third of total Space program costs. The rest has to do with spacecraft, instruments, data and their processing – in space and on the ground.

   2.2. This same ability and the need and opportunity to do (a) above will allow us – indeed will force us – to **standardize Spacecraft and Space systems at a subsystem level**. This idea was revolutionary at that time and still has to be implemented today – or could be implemented if we truly had a reusable Space transportation capability to all these orbits. The savings across the Space program would be dramatic and radical, in scientific, commercial and military Space missions. Indeed. Estimates were that these costs could be cut by up to 67% across small, medium and large Spacecraft. Standardization would be required if for but one reason: to facilitate the repair and updating of these spacecraft at a subsystem level, exchanging so to say blue, green, pink and whatever other color boxes, tasks even test pilots maybe capable of in the Space environment without graduate degrees in aeronautical or any other engineering field. Only a very select few Space missions were found to be "outside" the scope of such standardization. Instead of handcrafting each satellite like ultra-expensive Swiss clockworks, the age of standardization would have been introduced in Space, just as it was in the decades after 1970 in car manufacturing and many an other gadget and appliance industry.

   2.3. Simultaneously, **reliability** and **assurance of service** would be increased dramatically. For programs essential for the security of the United States, these requirements of **assurance of service in orbit** require an extraordinary expenditure of funds and assets to reach such assurance: for global coverage **at least three** such expensive multibillion dollar spacecraft are required in geo-synchronous orbits (numbers multiply rapidly at lower orbits), each requiring an **on station** replacement unit right next to each of these satellites (making for another three spacecraft), then each of these replacements requires a **replacement on the ground ready for launch**, so that the replacement unit(s) in orbit can

be replaced in orbit (another three units) **and** three more units have to move through the production lines to allow replacement of the units on the ground in case of need **for a total of four times** the nominal capability needed operating on station in orbit! Indeed we should be grateful for such “paranoia”, but anything less than such assurance of service would/could/has led to war in times were such capabilities did not exist. With the ability to revisit, repair and update assurance of service is increased to levels customary in ground based operations (twelve sigma or better in electronics), while at the same time reducing drastically the number of spacecraft needed for such assurance of service.

2.4. **Ability of in-orbit modernization:** with a subsystem design, replacement and repair capability the prospect exists of updating these expensive assets **in Space,** rather than replace whole systems or – worse – let old technology linger in Space providing obsolete services.

3. **Enabling New Space Missions:** in order to give as conservative an evaluation of the new Space Transportation System we excluded outright any and all manned missions. We did not want to rationalize the Space Shuttle simply and solely on the basis of man in Space: it would tilt the analysis much too much in favor of the Space Shuttle.

   So we set out to define an entirely unmanned Space mission program. Making use, however, of the extensive new capabilities that the Space Tug and Space Shuttle opened up: structures larger than could be carried by any expendable system, standardized and designed for repair, replacements, updates, maintenance. And entirely new classes of Spacecraft, be they for science, commerce or defense, whether in Low Earth Orbit, intermediate orbits or way beyond up to Geo/synchronous orbits. Dozens of new Space application missions where designed and outlined for NASA, the DoD and private enterprise to pursue once the Space Shuttle and Tug were fully operational. Here but a few examples in each of the areas:

   3.1. **Space Science:** one of our first visits in Princeton was to the astronomy department, chaired at that time by Prof. Spitzer. The result of these meetings was what today is known as the **Hubble Space Telescope**, mentioned already above. Where it not for the unique capabilities of the Space Shuttle, this telescope could never have been built, launched, repaired, maintained and modernized, up to and including entirely new capabilities not envisioned at the inception of this program.

   This single project and the myriad of discoveries made since with this magnificent instrument justify the entire Space Shuttle program, as well as the tragic death of the crews of Challenger and Columbia: what nobler cause than to die in pursuit of the ultimate questions of why we exist, where we came from and where the journey will take us in the future? Without Hubble we would be grappling blindly in a sea of ignorance,

devoid of the magnificent data Hubble has and will continue to provide.

But like Hubble we had defined half a dozen other scientific Space craft, some in LEO, some in HEO and some in GEO, ranging from radar to infrared to multi-spectral instruments of a size and capability hitherto unknown and unimaginable.

3.2. Commercial Applications: communications and remote sensing were the principal uses foreseen. Some of these applications would develop with or without the Space Shuttle, such as a vast range of communications and navigation satellites e.g. GPS, a variety of Global resources sensing satellites, low and high Earth orbit communication satellites at a variety of frequency bands. Many of these have come about by now, some still remain to be implemented – market conditions permitting.

However, we also had foreseen an entirely new class of satellites, with vastly expanded capabilities, requiring precisely the same type of capabilities and engineering approach as the one used for the Hubble Space Telescope. For but one example: we envisioned a new generation of **communication platforms in geo-synchronous orbit**, with on-board switching capabilities, vastly expanded power-requirements, on-board data processing and storage, with **tens of thousands of spot beams**, with satellite to satellite optical and laser communications allowing, once deployed, point to point communications to any place in the world, without any ground communications capabilities, allowing access to any and all data and information bases with simple, handheld devices.

Today, some of these capabilities have been realized with what we now call the ‘internet”. However, our vision went well beyond, in as much these Space based capabilities were not subject to any totalitarian government controls, able to make available the complete Library of Congress as if entering that Library, its catalogues and volume retrievals “on site”. We projected these capabilities to bring about the collapse of such totalitarian systems, that to a large extend were built on the control of information, access thereto and its distribution. Alas today we are still a long way distant from that lofty goal, with many a trend recently taking us in a somewhat different direction of more control and less access.

Because of the size of these platforms and their costs and constant technological change, direct access to these platforms, their repair, their updating, maintenance and modernization was absolutely essential, as well as the assurance of their high reliability of 99.999 plus percent.

For remote sensing of the Earth resources we envisioned a Global Resources Information System (GRIS) described in detail in the NRC papers of the Snowmass meetings of 1974. The effect on the distribution of world food supplies through the commodities markets alone accounted

for billions of dollars in annual benefits. Environmental, energy, geologic and other resource observations benefited as well, including such arcane applications as archeology. Many of these have become reality todate, as they can also be achieved with smaller spacecraft, not requiring the capabilities of the Space Shuttle and Tug system.

3.3. Defense Applications: at leas tone third of all applications foreseen for the new STS were defense related. They included some of the applications realized since then in navigation (GPS), in observations, in communications, albeit not to the extend possible if we had truly developed the full Shuttle and Tug capabilities, with vistas as to expanded uses of Space very similar to those cited for commercial uses above.

However, two outstanding mission – both shown (as to their results on the effectiveness and desirability of the Space Shuttle) – deserve special mention: **kinetic and /or laser based defense against ballistic missiles** attack. Building on the considerations of "Bambi" and the seminal paper by Max Hunter – a member of our team – of 1968 showing the technical feasibility (in principle) of a Space based laser defense against ballistic missile attacks – we included BOTH options in our analyses of 1971/72. On cost-effectiveness alone these two missions – while not necessary for a positive Space Shuttle decision would have significantly added (with a Space Tug to boost) to the uses of the Shuttle and its mission capabilities to revisit, update and modernize such new uses of Space in defense against weapons of mass destruction – globally.

3.4. Not included were a truly spectacular vision of future energy supplies from Space to Earth, namely large **Solar Power Satellite Platforms** of up to 100 square miles in area, first proposed by Peter Glaser of Arthur D. Little. One such platform alone will be able to supply up to 10 GW of electric power to any point on Earth.

3.5. Also not included in the analyses were any **manned Space flight missions** such as a Space Station, or Lunar missions or missions beyond. The reason, once again, were not to co-mingle the obvious missions and requirements of manned Space Flight with an analysis of whether a Shuttle and Tug were needed even without such missions. Indeed they were and the new horizons they would open were truly astounding.

Analyzing literally hundreds of different Space program scenarios, with any and all mixes of foreseeable Space missions and applications, we concluded at the end of 1971/January of 1972 that indeed a Space Shuttle and Space Tug were in the interest of the United States to develop, at a substantially reduced cost from the original plans of NASA (a two stage fully reusable design roughly a 707

on top of a 747 taking off vertically with internal hydrogen tanks etc.) saving the country billions of dollars in the development phase (cutting the RDT&E costs by 50% or more) AND allowing a cost effective, new range of Space operations and uses. This result was given to the NASA Administrator in my Memorandum of October 29th, 1971 (to assure consideration in the Final Design Selection process set for early November and still limited to two stage designs only) and a three volume report and separate Executive Summary of January 1972, documenting the extensive work done by our group in Princeton with support from Aerospace Corporation (Mission modeling) and Lockheed Missile and Space Corporation, the leading contractor for military payloads then and since.

The explicitly stated risk of Shuttle Missions: a one in fifty likelihood of failure.

Today, thirty plus years later, I would not change a single sentence, conclusion or recommendation made in 1971, except to highlight the concluding observations to NASA: the economic basis for the Space Shuttle and Tug were sound and solid – AS LONG AS NASA AND THE NATION HAD AN ACTIVE SPACE PROGRAM ALONG THE SCALED BACK SCENARIOS OUTLINED AND USED BY US.

Never, ever would it have occurred to us, that NASA and the nation would abdicate the pursuit and conquest, indeed domination of Space.

II. A 30 YEAR ROAD TO DISASTER

4. The initial Space Transportation System Recommendations of 1971.

The 1972 decision to proceed with a new Space Transportation System – comprising the TAOS Shuttle and the Space Tug – was the last significant, courageous and strategic Space program decision assuring an aggressive US Space strategy for the rest of the century to well into the next millennium: all this at an affordable budget profile substantially less than that expended on the Apollo program of the 1960s, the vision for which President Kennedy and his generation will be remembered in millennia to come.

Without summarizing the whole 1971/2 report here the salient technical transportation components recommended at that time:

4.1. TAOS instead of Two Stage Fully Reusable Shuttle:

The TAOS Orbiter Shuttle represented a substantial reduction in development costs, risks and schedules over the desire by NASA to develop a two stage fully reusable Orbiter AND Booster, with the estimated development costs reduced by a factor of three to four (from 50 to $60 billion in 1970 dollars to 15 to $20 billion for TAOS, a savings of

at least $40 billion in costs alone;

4.2. **A reusable Space Tug:**

To assure access to all Earth orbit missions to the new STS and its new philosophy of payload standardization for in orbit repairs, refurbishment, updating and rescue for high mission availability;

4.3. **An Ambitious Unmanned Space Missions program**, including:
- 4.3.1. All “conventional” DoD programs currently deployed
- 4.3.2. Two novel DoD missile defense missions, one “kinetic” (then called ‘killer bees’), one laser based (Max Hunter’s concept of 1968);
- 4.3.3. “Conventional” science and commercial programs such as communications, observations, navigation and life sciences programs;
- 4.3.4. Entirely new class of science and commercial space capabilities such as
  - 4.3.4.1. Large Astronomy Observation platforms, e.g. the Hubble Space Telescope and several others which availed themselves uniquely of the new STS capabilities and
  - 4.3.4.2. Large Space Communications platforms of entirely new dimensions in geosyncronous orbit, accessible by the Space Tug, and allowing global point to point communications without any ground networks. One such proposal envisioned making available the entire Library of Congress via these platforms to any and all with simple handheld devices.

4.4. Enabling whatever **Manned Space Program** the US might wish to pursue as a “side benefit” of these capabilities.

Had NASA and the nation fully pursued these programs, and fully developed the STS vision of the early 1970s in the afterglow of the Apollo program achievements the dominance of the United States in Space would have been absolute. Some of these programs have immensely contributed to changing the strategic perceptions and relations anyhow, even without their full implementation (e.g. SDI – missile defense). Others, indeed most still languish to be implemented.

The fact that others have been even more laggard in the pursuit of Space enterprise and exploration is no excuse for the US to have failed so miserably in advancing beyond the known and doable of the late 1960s. The course charted out then still remains to be taken. Most notably in manned Space flight. Yet NASA and the process of the Space Interagency Group managed to botch even the modest programs actually pursued since then, which is the reason we are in the precarious state of today, a situation that requires leadership – not timid extrapolations from the morass of inactivity and accounting acrobatics we find ourselves in today.

That road to the current disastrous state comprises the following ‘milestones’:

5. **Early Open Questions and Compromises 1972**

After having identified the TAOS (Thrust Assisted Orbiter Shuttle) as the most cost-effective of “hybrid” Space Shuttles I assembled the top experts from industry and NASA in Princeton in June/July of 1971. We had to meet in a dilapidated hotel along route 1, because university grounds at that time were “off-limits” to the industrial military “complex”. During that week of meetings all the critical issues came to light, if only due to how the meeting was set up: it pitted all the different engineering approaches and groups against one another, in a truly historical debate, sometimes reaching rather high decibel levels. What was most remarkable then and may I say since, where the following:

5.1. **Solids vs. Pressure-fed “assists”** to the Shuttle at take-off: having eliminated the need for a 747 size reusable booster as envisioned by NASA in its original desires submitted to us for evaluation, we had to provide the “extra lift” with parallel rocket assists. Two principal options were considered: either solid rockets, such as those produced by Thiokol for expendable rockets, or – like the main external tank – two additional pressure fed rockets using the same fuel (oxygen and hydrogen) as the Main Space Shuttle Engines.

The former had an “irreducible risk”, among others as to simultaneous ignition and the inability to cut off such ignition should problems develop at or during launch. Pressure feds not only could be shut-off in case of emergency, but with “cross-feed” from the other tanks (Main tank and/or the other parallel burn booster) ALL engines could be fed from whatever tank(s) were available or operable. Indeed of all the Shuttle launches the most impressive was the one that did not take off AFTER the SSMEs had ignited (Shuttle Main Engines) but BEFORE the Solids had ignited, quite a feat. The worst Shuttle accident has not happened: ignition of only one of the Solids and a “cartwheel” of the Shuttle and tanks and solids right on the take-off stand.

Yet this is what we discussed at those meetings, leaving the choice open. The reason: pressure-feds with cross-feed had not been tested operationally on such a scale and required an additional $500 million in RDT&E costs when compared to solids.

Another draw back of Solids: they would double the cost per launch. The agreed consensus: whatever decision NASA made on Solids vs. pressure-feds we would move rather quickly to adding pressure feds to Shuttle operations, simply to reduce risk and the high cost per flight.

5.2. **Thermal Tiles vs. Metallic Composites Heat Shields**: the other big issue in these meetings was how to provide for the tremendous heat arising during re-entry into the atmosphere. Grumman was considering an ingenious scheme related to tiles. The other major option was to develop new metallic/composites able to withstand these stresses and environs.

Again, the tiles approach was more immediate and required less new materials development. The metallic protection, while requiring a significant materials development and testing program would dramatically reduce turn-around times, refurbishment needs and thereby launch costs and times.

5.3. **Space Shuttle Main Engines**: with ignition at lift-off and burn all the way to Earth orbit, significant new requirements were imposed on rocket engine technology. Indeed, the development and total success of the SSMEs to this date constitutes the major technology achievement in the Space Shuttle program, a feat no other space-faring nation has accomplished to-date. Yet the uncertainties at the meetings in that June/July week were significant, the RDT&E inescapable and hence committed to.

5.4. **Gradual Evolution of Space Shuttle** to a fully reusable Spacecraft: about to force NASA into an unpleasant compromise, namely to give up on its dream of a fully reusable, two stage Space Shuttle of incredible technological challenge in favor of this “hybrid” TAOS approach the possibility of the gradual evolution toward a fully reusable Space Shuttle with future procurements was a core component of these considerations. This vision was as follows:

5.4.1. **Initial fleet size and subsequent procurements**: Based on launch requirements, anticipated “attrition”, material and technical obsolescence an initial procurement of five Orbiters was proposed with additional Shuttles to be procured at a rate of about one a year, for **a total of between nine to twelve for the initial decade** of full operations.

5.4.2. **Two launch sites – ETR (Kennedy Space Center) and WTR** (Edwards in California for polar orbit launches) were anticipated.

5.4.3. **Gradual Technology Upgrades:** As the experience and technology progressed certainly the solids would be replaced by pressure feds, the tiles with metallic composites and payload capacities could be dramatically increased with e.g. a dual parallel launch of two Shuttles simultaneously, with the tanks between them, vastly expanding the mass and size of payloads to be transported to LEO.

5.4.4. **Evolution toward a Fully Reusable Shuttle:** Ultimately even more radical innovations could evolve from the TAOS, such as the “Stage and A Half” envisioned by the team member Max Hunter, with up to sixteen Shuttle engines and delta wing shaped fuel tanks attached

(and recovered).

6. **The October 1971 Compromise on Solids vs. Pressure-feds**:

as the Shuttle design decision by NASA came to a climax in late 1971 I decided to write NASA the Memorandum as to our conclusions concerning the Space Shuttle, configurations and options. That input was needed before NASA made a possibly irreversible decision in early November 1971.

In addition to the TAOS configuration choice I had come to the conviction that clearly for reasons of cost per flight and risk of flight and intact abort requirements the ideal option was the pressure-fed version of TAOS: every aspect of Space flight operations indicated this preference, yet I was convinced that giving NASA a “choice” between Solids and Pressure-feds rather than an outright recommendation for pressure-feds) would invariably lead to NASA choosing Solids, for two “reasons”: first, Solids meant $500 million less in funding requirements in the 70ies and, second, Thiokol was from Utah and produced Solids and so was the Chairman of the Senate Committee presiding over these issues (Senator Moss) and so was the Administrator of NASA. No other component subsystem of the Shuttle could be produced there. So NASA would invariably come to a preordained (wrong) conclusion in this matter.

Having drafted the Memorandum I went to see Oskar Morgenstern, my professor, to have him co-sign said memorandum. After explaining the need for such an input and the various attendant open issues Morgenstern would only agree to co-sign the Memorandum with the two options left open. I did not have the courage (or gumption) to send the Memorandum without his support. Just in 2002 I learned upon a visit to Princeton at dinner with the 1971 Science Advisor under Nixon, Mr. David, that Fletcher had come to him in early 1972 on this very issue and that Davis had not recognized the need for him to intervene, which Dr. Fletcher was basically begging for, not realizing that if left to NASA there was no choice. Fletchers words to Davis: “there was all this pressure to go for Solids while pressure feds clearly held promise”. Davis did not intervene and asked Fletcher to resolve matters “in house”.

The other major component of that Memorandum of course had to do with the presumption that NASA and the nation would have a Space program to go with the Shuttle.

Thereafter success was nearly total. A desperate effort was mounted by OMB to “downsize” the Space Shuttle to less than what was required to carry the whole range of civilian and military payloads. To swart that attempt we literally “camped out” at NASA headquarters for fully ten days, day and night, working with our support teams in Princeton, El Segundo (Aerospace) and San Jose (Lockheed MSC) with the central point being that no costs were being “saved” with smaller configurations. Indeed, re-entry by a larger delta winged

spacecraft was less problematical than smaller craft, since the total mass was not that much reduced by downsizing whereas the protective area slowing down the Shuttle during reentry indeed was reduced by such variations. We won that battle hands down.

The hearings in the Senate and House were equally extensive and – in the end quite satisfying: the lead opponent of the Space Shuttle program was a Senator Mondale, who in the footsteps of Senator Proxmire tried to make a "name" for himself as a big aerospace program "killer'. After everything was discussed, presented and reviewed, including "showdown" sessions with the proponents led by me and opponents led by Mondale, Proxmire turned to me and said – in front of Mondale: "I would like to compliment you for the work done and the thorough analyses. While I will not come out in favor of this vast program I will certainly not oppose it." That meant the approval of the program. Numerous investigations and exams by GAO and others followed, including a Ph.D. thesis years later by Hum Mandel, that after the facts and despite serious delays in the procurement schedules confirmed that our estimates given in 1971 as to the costs of the RDT&E of the Shuttle program came within 5% (!) of actual costs as the program was realized.

But all was not well.

7. **Price Controls, Inflation and the Shuttle development:**

to finance the war in Vietnam and adverse to increasing taxes in an up and coming election year, Nixon demonetized the Dollar, removing overnight the sacred pledge to redeem all dollars in Gold and imposed price controls, somehow the logic being that with prices under "control" there could be no inflation. What resulted after 1972 was a period of the worst inflation ever experienced by the US in the 20th century. How did this of all things affect the Shuttle?

Well, NASA had made a "pre" inflation budget deal with OMB. NASA would develop the Shuttle as shown in the budget profiles, come what may. Well, what did come was inflation and OMB held NASA to the nominal numbers agreed to. The result was a disaster: programs were cut back, "non-destructive" testing was invented, instead of reality simulations took over and, most importantly, at every junction where NASA had the choice to do the more expensive but technologically advanced component, NASA chose the cheap way out: on Solids vs. pressure-feds, on heat tiles vs. metallic/composite shielding on upper stages, whatever and wherever. The program was stretched, another "fund-raising" mechanism in Government accounting and procurement.

8. **Cancellation of the "European" Space Tug:**

as we saw, over 60% of all Space missions are above and beyond LEO, the orbits reachable by the Shuttle alone. To implement the vision and potential

outlined for a reusable Space Transportation System required a reusable Stage – the Space Tug. But NASA had no such funding.

So the first approach was to talk the Europeans into joining us in the development of the STS, with the Europeans (ELDO, a predecessor of ESA) developing the Space Tug. I went on a crash program and after a 12 months effort things had fallen into place: ELDO agreed to fund and build the Space Tug in co-operation with NASA. AT the final presentation to a meeting of ministers in Brussels I observed, however, when asked about the usefulness of the Space Tug and its technology (reusable, re-ignitable upper Ox/Hydrogen propulsion systems) that with 60% of all payloads needing such a stage and given the importance of these missions, the US Government might well ask the Europeans NOT to proceed and reserve the task of this development to the US. It took less than six months for NSA to be directed by the Space Interagency Group – that anonymous direktorat of un-elected officials of the Space bureaucracy – to direct NSA with the cancellation of any such agreement with ELDO/ESA.

Instead the DoD initiated a “long march” to nowhere, succeeding in the next decade to literally spend anywhere from $3 to $5 billion – some of it with and through NASA, with all programs failing either in infancy or in technological still births: the IUS (interim upper stage), the TOSS, the Centaur-in Shuttle, and then some. But in any case, the facts are that no such stage exists to-date. Meaning, 60% plus of all the potential missions just went “down the drain”. Worse yet: the infrastructure to maintain the launch capability for these “out-of-reach” missions had to be kept in place, one of the key reasons not to pursue a fully reusable upper stage to begin with, as seen by these geniuses. With it went a whole range of truly innovative new Space applications, be they military, scientific or commercial. The negative impact of this single decision – and its consequences for the decades to follow, can not be overstated. Few are aware of this even today.

9. **Fatal Cutbacks - “Revenge” of the OMB Accountants**:

with the advent of the Carter-Mondale presidency the true disaster for the Space Shuttle program set in. With Mondale putting his “experts’ into key “second” positions throughout the government – principally also the OMB – a veritable blood bath set in for the Shuttle program. Mondale made sure he would be proven right as to the deficiencies of the Space Shuttle. The components of this demolition effort was varied and devastating:

9.1. **Cutback of Shuttle launch sites** from two (Eats and West Coast) to one (East Coast): these “savings” were arrived at by some obscure (obscurantist?) logic, that fewer launch sites would mean fewer costs. Wrong again: what it meant was that no polar launches could be made with the Shuttle, again leading to a further loss of applications and traffic. Of course, the Vehicle Assembly Building at Vandenberg had already been started and any a billion dollars invested therein. In addition, it also

meant critical DoD “bureaucratic” support in annual budget battles. Somebody in SIG and the White House did not like the Shuttle.

9.2. **Cutback of Shuttle Orbiters:** the most devastating decision was to cut back the orbiter procurement from five to four – the original intend actually was to cut the fleet to three. This decision, combined with the closing of the Western launches of the Shuttle – practically meant the end of the Space Shuttle long before its first launch. Not only were the missions for the Shuttle cut back substantially to a debilitatingly low level, negating most advantages, if any, for reusable systems – but by “freezing” the procurement the technological evolution of the Shuttle beyond the initial compromises was foreclosed.

9.3. **Disastrous budgetary implications** were that the end result of this “policy” would be substantially added expenditures, if only the additional $2 Billion per year for maintaining the Titan launch infrastructure and capabilities, leaving aside for the moment the several billions already spent on the Western Test range to actually launch Shuttles from there: the US could have procured Two Space Shuttles a year just for the Titan closedown and saved money!

As this “process” was taking shape I repeatedly traveled to Washington, trying to prevent such a fatal decision. In early 1978 a confrontation took place in OMB – which I still have on tape (taken by Johan Benson of AIAA) wherein the outcome was an agreement that I could venture out to get private funding for a Fifth Orbiter in return for all the non-US Government uses of the Shuttle. The next five years I would pursue that prospect – successfully in the market place, only to be turned down – again – by SIG, after raising the requisite financing, not only for the Fifth Orbiter, but also for the commercialization of the Titan launch vehicles. However, that is a separate story, except for the basic goal being to actually shame the Government into the procurement of additional orbiters, if only to provide for the event of catastrophic losses. To no avail.

9.4. **Lack of Space missions making use of Shuttle capabilities:** once NASA had the task of developing the Shuttle and mired in the yearly battles for the budget to see to its development, all other programs were subordinated or forgotten in favor of this single development.

While astronauts were completing the spectacular missions to the Moon – through Apollo 17 – launched a Space Station larger than the “current” ISS – called Skylab – and other remnants of the Space effort of the 1960s we were about to close down the opportunities for the 1980s and beyond. NASA was (deliberately?) unable even to raise a $100 million or so to boost Skylab to a higher orbit and so preserve our Space station capabilities into the 1980s – a failure of titanic proportions in its shortsightedness, may be villainy. The “conjecture” by SIG was that –

without a Space Station in orbit the “next” program for the 1980s would be – you guessed it – a Space Station for the 1990, albeit smaller than Skylab and international as well. This alleviated NASA and SIG from any and all thinking of truly new missions and applications, such as the ones outlines by us based on the work of hundreds and thousands of the best aerospace minds. All this before even the first Space Shuttle launch in 1981.

9.5. A Disaster that did NOT happen: the near failure of the First Shuttle (Columbia) Launch in 1981.

Disasters lead to great inquests, deep questions, self doubt, sometimes a re-orientation of policies and programs either foreclosing or opening up entirely new “futures”. One disaster that nearly happened, was about to unfold, obvious for all to see was the very first Space Shuttle launch. If one goes back and watches the video sequence of that take-off something entirely unexpected happened: the shock-waves from the ignition of the Shuttle Main engines (a few seconds before the ignition of the Solids and take-off) traveled right back into the Shuttle structure, shaking the configuration and nearly breaking it up. What had happened was that the water stored below the take-off ramp to absorb the shockwaves from the ignition were scaled based on the Apollo experience, wherein all engines of the first stage ignited simultaneously – rather than sequentially. Nobody had anticipated these “second order” effects of sojourning on the launch pad while waiting for the Solids to ignite.

Had the Space Shuttle broken apart right there on the ramp on its maiden flight, for all to see in one of the most spectacular “fireworks” ever ignited, with total crew loss and who knows what else (e.g. if some of the components had spun out of control toward the viewing stands…), it would have been the end of the Space Shuttle program right then and there.

But by some fluke of nonlinear dynamics – or “robustness” of the system – this did not happen. But because of that, was the Space Shuttle less risky, or manned Space flight, or Space exploration. And in reverse: had that accident happened, would the Space Shuttle program and manned Space flight have been less worth pursuing? Most certainly not, at least in my opinion, yet such accidents and non-accidents overridingly shape the “directions” from the limited “vista” by SIG-Space of the US Space program.

10. Attempt to Salvage Fatal Cutbacks in Shuttle Program: Private Funding for Orbiter V.

10.1. Round I of the private funding for Orbiter V (the Carter Years)

Fresh from the “mandate” to arrange private funding for Orbiter V – obviously with OMB convinced no such effort would succeed) I arranged an aerospace consortium around Boeing as the main (or lead) investor. I chose Boeing for the pursuit of this first attempted financing because Boeing had been “left out” of the Space side of the aerospace business: having done the Saturn II stage in the Apollo program and with significant involvement in the Skylab program Boeing had gone empty on any and all major Space Shuttle components. So there was a desire to get “back in”. Also, Boeing’s capital and sales base, when compared to that of the rest of aerospace industry, was firmly grounded by then in commercial markets. In addition, Boeing had the largest operating experience and data base on aircraft operations, which might be applicable to Space Shuttle operations as well.

Such a consortium did form around a Space Transportation Company concept not dissimilar to the Comsat model established in the 1960s for Civilian Space Communications. It included Boeing in a lead role, Martin-Marietta, United Technologies, Thiokol, North American Rockwell and some other companies.

But just as the venture was about to take off, “infighting” broke out between the consortium, each one trying to grab a larger share of the pie. In the end, what it really came down to was the statement by the Space Shuttle contractors that Boeing had little, if anything, to contribute, forgetting that none of the other companies had the capital base nor the operations experience of a Boeing company. For that matter, none of them had the gumption to actually go out into the market place and risk their own funds in pursuit of larger future rewards: they were much better off living off the Government dole, with contracts locked up for decades to come “as long as nobody upset the apple card”.

10.2. **A Trip to Paris and the Founding of Arianne Space:**

Having raised the prospect of private funding of the Fifth Orbiter and the formation of a Space Transportation company to see to the marketing of this capacity, French aerospace and government officials invited me and officials from Boeing (Gil Keyes) to join for a one week meeting in the French Senate to explore what Europe should do in operating the Arianne launcher program. Our proposal was simple: form a company under private corporate law, involve banks, financial institutions, aerospace companies and government institutions and keep Government oversight functions via the Board, basically the Comsat example set under President Kennedy for Space communications in the early 1960s. Any other approach was not likely to succeed in the market place.

The French and the Europeans formed what today is known as “Arianne-Space” within six months of that meeting. Arianne Space is today the

most successful Space launch company in the world.

10.3. **Reorganizing under Reagan:**

On February 29th 1980 some of us of High Frontier met with Mr. Ronald Reagan in the “wilds” of New Hampshire and briefed him on the prospects of ballistic missile defenses and the need therefore. At lunch Reagan said that should he become President he would initiate such a program. That very afternoon the “incident” with George Bush Sr. occurred as to the number of participants in the evenings discussion: Bush wanting a one on one with Reagan, to the exclusion of all others. Reagan thought that unfair and settled the issue with: “I paid for this event and I have decided that all shall be given a chance to participate”. Which ended the primaries and the rest is history.

I also came away determined to see more than ever to save the Space Shuttle program set for it by the Mondale reign in the executive offices and Space matters. I had come to the conclusion that an aerospace consortium was not likely to succeed for the reasons stated above. Given the strong and positive case for the Fifth Orbiter I decided to go at it via a purely financial route, with aerospace becoming contractors, a role they had become accustomed to.

To such purpose I incorporated the Space Transportation Company and brought a group of investment bankers into the venture, former partners of Morgan Stanley, White Weld and Co. Eastman Dillon and various legal and accounting talents. After the business analyses were completed and a framework of understanding worked out with competent NASA officials, Prudential came on board, with William Field Prudential had to reinvest every year about $6 Billion, or $30 Million each business day. The case for the Shuttle, subject to reaching agreement with NASA, was ironclad. Prudential had an additional motivation: being the largest insurance company, invariably Prudential was also the premier financing entity of any and all commercial Space ventures, principally communications satellites. What good were these “investments” if they could not be launched to orbit?

This led to an additional “complementary” investment: commercial launch back up with expendable rockets. After a survey of available options, and aware of the need to back up any and all Space Shuttle payloads that also might develop in the future, there was one and only one system fulfilling such requirements: the Titan family of launch vehicles. After intense negotiations we signed an exclusive worldwide agreement with Martin Marietta on October 29th at Cape Canaveral in Florida on occasion of the first launch of the Titan 34 D, later to be christened the Titan III.

In 1982 Federal Express joint the SpaceTran venture and President Reagan formed the Space Commercialization task force. The road to

substantial private funding and involvement in US Space transportation seemed open and imminent. At the UNISPACE meetings in Vienna, Austria in the Summer of 1982 we celebrated the agreements in principle and the then NASA administrator, Jim Beggs, seemed ecstatic.

However, we had not checked with the “hidden” Government structure, the Space Interagency Group, a group determined to “save” the United States and mankind from any such undertaking. And the “obstacles” to such enterprise were NOT buried in the Department of Defense, the usual villain of the academic community of “experts” and “cognoscenti”, but the civilian side of the Space government community.

Worse yet, whereas the President and the White House clearly were on our side and the side of more commercial involvement, it was this civilian government core of bureaucrats who saw their “well earned” spot in the sun of government power whittle away just at the point of “fruition”. Here some examples:

10.4. **On Expendable (“Rocket”) Space transportation:** Instead of following the Comsat example on how to organize US Space activities in areas of commercial potential and of national security concerns (and Intelsat for international uses) or follow the example just set by Arianne Space (a combination of financial, industry and government investments) the USG set out to splinter US Space activities and invented yet another bureaucracy at the US Department of Transportation which swiftly set out to foster all US expendable rockets aerospace companies and systems and incentivise – in a rush of hubris – even new ones, all of which subsequently failed or cost the sponsoring companies untold billions in unrecovered costs, or costs burdened to government contracts. Of course, Space Shuttle operations and marketing were to stay a monopoly of the US Government, in this case NASA.

However, when a private group – SpaceTran - actually was about to win in international competition against Arianne Space and against US subsidized government Space Shuttle launchers the $1 Billion Intelsat VI contract of launches, fully coordinated and agreed to with the US Air force and Department of Defense, this same SIG and NASA intervened to disallow the use of launch pad 39 B already agreed to by the Air force, thus abrogating the successful competition which subsequently was won by Arianne Space: better a bunch of foreigners that US private Space enterprise let loose (Spring of 1983). After meeting with Hans Mark in the Spring of 1983 , then the Deputy Administrator of NASA and chief SIG honcho, on these issues Fred Smith, Chairman and CEO of Federal Express turned to me while outside the still open door and in a loud voice commented to me:” Klaus, this was the first time in my life that somebody lied to me, realized that I knew he was lying to me and then continued lying to me”! Of course, Hans Mark had professed how supportive he

was, but…

10.5. **On Privatizing or Commercializing Remote Sensing**: Again, rather than follow the Comsat precedent set in the 1960s and despite the explicit desire and intent of President Reagan, SIG set out to sabotage the privatization of remote sensing, be it of land and ocean resources, be it of weather satellites. The very day President Reagan announced his desire to commercialize and privatize these government activities (Spring of 1984) all the media (newspapers and special television reports) had lead articles on how stupid any such endeavor was judged to be by worldwide comments and reactions well orchestrated by SIG and their ideological co-brethren. How could it be that even before the President had announced his policy US and world reaction was negative to any such restructuring of USG monopolies?

Yet worse was to come: as some of us in industry had organized an international consortium to do exactly what President Ragan advocated – commercial remote sensing using the Space Shuttle and combining Comsat, private US investors and international aerospace firms – in a panic of regulatory overreach SIG imposed what euphemistically was titled the Landsat Commercialization Act of 1984 wherein Title 4 of that same act outlaws any and all private ownership of original Space data (!) this despite the fact that we already had a signed contract with NASA wherein under specific and explicit standard agreement all those data indeed were to be our private property. SIG had to revert to such constitutionally suspect brutality since otherwise they had no “handle” on our making untold millions from applications and technology SIG was negligent of having thought about or implemented. (In a meeting in the Roosevelt Room of the White House in 1984 with us it dawned on SIG that they had totally missed the fact that we did not need US Government frequency approvals as we put all the data on other media – hence SIG could not dictate to us “fair pricing” policies set to ruin any attempted private activity).

The fact that the same legislation also outlawed the operation of any and all television cameras in Space and from Space in clear violation of first amendment rights was of little, if any, concern to this policy group.

Now, TWENTY YEARS LATER, the same Space bureaucracy finally has come around to conclude that indeed it is advantageous and efficient for the US Government to avail itself also of commercial, private remote sensing capabilities. How much further could we have advanced by now, at what untold savings to the US Government: NIMA and its predecessors in the 1980s would have saved up to $1 billion in multispectral and panchromatic imaging and map making alone had they allowed the Stereo MOMS venture to proceed in 1984.

10.6. **Turning Down Private Funding for the Space Shuttle:** Instead of jumping at the opportunity to provide a "zero Government cost" back up and continuation of Shuttle production capabilities NASA did everything imaginable to sabotage the venture. First it did not believe that such a venture could be funded on the merits, then – with Prudential Insurance and Federal Express joining SpaceTran – NASA went to infinite length to "study" the economics of the venture (what for?), while all along we were not asking for any government guaranties except an assurance of six launches a year from the fleet of Shuttles with all incremental costs reimbursed to NASA. After years of negotiations and deliberations NASA turned down our proposal for funding the Fifth Orbiter (at a negotiated price from Rockwell of about $1 billion) because NASA alleged we would be making too much money and not taking enough risk – like loosing an orbiter: that is the NASA testimony in March 1986 after the Challenger explosion. Orbiter V would have been rolled out in July 1986. Instead the US could not launch any spacecraft for over two years and the Fifth Orbiter cost US taxpayers about $3 billion.

11. **The 1992 Columbus 500 Space Sail Competition:**

Having failed to bring about substantial private and commercial involvement in the US Space program I made a final attempt to foster and bring about such independent and market based involvement of non USG people. The Columbus 500 Space Sail Cup was conceived by me and the Hon. James Symington, former Chairman of the House Space and Sciences committee in the 1970s. Needless to say, despite overwhelming US participation and proposals NASA could not be moved to facilitate or support any such effort. As a result the only group actually launching such a sail was a Russian team led by the very same Vladimir Syromiatnikov of Apollo Soyuz fame: on February 4th 1995 the first Space Sail set out and stayed in orbit for several days, substantially longer than a similar first, the flight of the Wright brothers nearly 100 years before.

12. Many other examples and many other ventures and enterprises could be added to this "honor roll" of ill conceived, self-serving , if not mean spirited, policy decisions of SIG in their pursuit of preserving the USG monopoly on Space and access to Space: any venture likely to fail SIG would consistently support, any venture likely to succeed outside the boundaries of absolute and total USG control they would set out to sabotage, prevent, if necessary by ex-post-facto legislation.

III. FAILURES / OMISSIONS IN COLUMBIA DISASTER

Obviously the Commission investigating the Columbia disaster has a much more detailed list of issues and questions as to the causes that led to Columbia's fateful last flight and loss of life. I am not privy to any of those considerations and

discussions, so the following issues that are raised in my mind may well be extensively covered. But with what has become public so far I am disturbed by the following broader issues:

13. **Lack of In-Orbit Rescue and standby capability:**

Whereas the media and the Commission go to great depth on why NASA did not request coverage by NRO/NIMA capabilities for an assessment of the state of Columbia after launch the question NOT asked is What could NASA have done about it whatever these images might have shown? The obvious answer is: nothing, because NASA refused to and/or was directed by "statute" not to avail itself on these "national" Space Transportation infrastructure assets of "foreign" capabilities, namely the extensive docking, re-supply, rescue and standby capabilities developed by and with Russia over decades past, such as under the Apollo-Soyuz program, the Shuttle-Soyuz program, the Shuttle-MIR Space Station program and the ISS-Soyuz capabilities.

I was utterly dismayed when NASA agreed to – without protest, resignation or other act of protest – to the statutory prohibition of availing itself of "non-US" capabilities for the ISS (and apparently also for the other components of the STS infrastructure) just to come up with a "rational" for a multibillion Crew Emergency Rescue Vehicle (CERV) capability. A cost efficient CERV capability exists – and is now being demonstrated – with the Proton-Soyuz rescue and support for the ISS crew, including my friend Don Pettit.

Why has NASA advocated/gone along with the "statutory" prohibition of "non-US" capabilities, which have proven and now continue to prove efficient, reliable and very, very cost-effective, rather than develop with the meager resources new space transportation capabilities so utterly needed – and totally neglected – by NASA over at least the past 25 (twenty-five) years (see section II below)?

Clearly SOME emergency was foreseeable and CLEARLY an easy, reliable rescue capability existed and COULD/SHOULD have been procured and deployed, but was not. The rank incompetence of what obviously is the deliberate process of the Space Interagency Group – in the name of a totally misunderstood "national security" strategy aimed at US monopoly and destruction of competition by any and all (private, international, even other agencies not "privileged" or anointed).

What could have been one of the great rescue missions of seven Shuttle astronauts by a Russian emergency launch and rescue of "our" astronauts – equal in excitement and goodwill as the splendid Apollo 13 mission – instead saw the helpless burn-up of the Columbia crew under a veil of ignorance.

More to the point: was the ignorance "willful", in the sense that it would make no sense to ask top management for requesting outside agencies for

obtaining data and information that only would add to the tragedy – indeed expose the endangerment of true national security due to the "statutory" prohibition of providing efficiently for such security, the security of the Shuttle and Space Station flight crews? After all, in this age of accountants, why "waste" precious resources for data and information that, if confirmed, would not allow any action whatsoever to "safe" the astronauts, indeed would only prolong and dramatize the agony globally and "live", in real time?

It is a very lame statement to then say to the US public and the media "that no statute was/is being violated by the Soyuz rescue of the current ISS crew as no US funds will be expended in that rescue".

A less cryptic statement might have been:

"Because of the special interest legislation mandating NASA to duplicate existing capabilities for providing for the re-supply and rescue of ISS and Shuttle crews in orbit and prohibiting US Government expenditures for providing for such outside rescue by NASA, the lives of seven astronauts were in all likelihood lost due to such lack of capability. Furthermore, NASA is now greatly indebted to the extraordinary offer by the Russians to come to the aid of the ISS and its crew at their expense, as current US statutes prohibit NASA from even contracting for such emergency rescue missions."

14. **Age of Columbia as a contributing Cause to the Disaster:**

The statement immediately after the Columbia disaster to the effect that Columbia had flown but a few hundred hours whereas civilian and military aircraft fly tens of thousands of hours and therefore the "age" of Columbia by implication had nothing to do with the disaster is one of the more unfortunate statements after the disaster - and a disaster all by itself.

Lest this statement was drafted by "communications" specialists trying to absolve with pre-emptive spin even the appearance of possible NASA management flaws in the operations and procurement philosophy of the Space Shuttle program the statement is obviously devoid of any aeronautical understanding of the totally different aerodynamic environment of Space flight as against experiences "enjoyed" by Bonus Mileage veterans of civil aviation flight. Even the basest knowledge of rocket launch environment stresses (acoustic, mechanical, etc.) should have prevented the use of such a statement. But since it was made it glaringly highlights a lack of basic understanding or seriousness which the topic at hand – manned space flight and safety – should demand. But then NASA has been in denial of such issues soon after the inception of the STS program initiated in 1972 (see Chapter II above).

The potential loss of orbiters always was a fundamental part of the initial assessment AND procurement philosophy of the Space Shuttle program, disastrously abandoned in the late 1970s and left uncorrected after the

Challenger disaster. One principle one was MATERIAL FATIGUE. The others included many additional factors not least of which technical obsolescence, the need to replace “improvisations” such as thermal tiles, solid rocket assists, avionics, other materials and actual flight experience into the CONTINUING PROCUREMENT OF ORBITERS, WITH AN INITIAL BATCH OF FIVE TO BE FOLLOWED BY ONE NEW ORBITER EVERY YEAR OR TWO DEPENDING ON ACTUAL FLIGHT LEVELS AND EXPERIENCE. This philosophy was deliberately abandoned due to budgetary and “institutional” reasons certainly by the end of the 1970s.

The loss rate of orbiters was estimated by us in 1971 to be around two in 100 flights, a number frighteningly close to the actual experience. THIS RISK CAN NOT BE REDUCED BY THE FLEET OF THESE 1960S GENERATION ORBITERS WHATEVER ONE WERE TO EXPEND.

The risk factors were not enhanced by the “discovery” in the 1970s – not least for budgetary reasons – of the new panacea of “non-destructive testing”, as if simulations and computer runs ever could be a substitute for testing and measurements until actual failure such as, sadly, the one now experienced again with a live crew.

Rather a continuity of orbiter procurement and upgrading was needed throughout these decades and in decades to come, with recurring losses from time to time – if one were serious about the future of manned space flight (Chapter IV below). The “recurring losses” in missions of exploration were well in excess of 50% (only a few dozen of the 100+ Chinese ship returned in 1423 from their worldwide expeditions, only one in ten trading missions to the East paid off for Spain, Portugal and later England during centuries past) and at least the “West” persisted in the quest of manned exploration, to the benefit of all of us here today in the Americas.

Columbia failed in part – or possibly mainly - because it was the oldest, overstressed ship with unpredictable (“non-linear”) material and other failure modes.

But let not these immediate issues and causes for this recent disaster obscure the 30 year road to disaster due to fundamental program management issues and false “compromises”.

IV. WHERE DO WE GO FROM HERE?

Looking now at the shambles and ruins of 30 years of ill-begotten SIG policy and NASA “management” of Space transportation and the US Space program, where should we go from here?

15. NASA's "New" Strategic Plan: Abandoning Manned Space Flight?

The NASA administrator just proposed NASA's "new" strategic plan for the decade(s) in the briefing by the NASA Administrator O'Keefe on Thursday, April 17th, 2003. Herein NASA 'courageously' proposes to terminate the Space Shuttle program (over twelve to 15 years), to substitute therefore a multibillion "aerospace" plane which is nothing but a reusable astronaut rescue capsule launched on an expendable rocket – a "vision" soundly rejected in the early 1970s – and a termination of any manned Space exploration: the vague hint at possible human support functions for establishing robot structures at L1 (or L2,…L5, or wherever) is not even a fig leaf covering the absence of any intent to see a United States presence in the manned exploration of the Moon and the solar system, or the stars. Yet this "sinking of the US Space fleet" was couched in language that to the unsuspecting listener might actually sound as if our quest were to continue: not a single headline in the media appeared highlighting this historical abdication by this NASA and this president. At least the Chinese accountants running government affairs in 1423 knew what they were doing, and doing so at the express orders of the successor to Zsu Di.

16. A Program worthy of the United States, at little (if any) extra cost:

16.1. **The First Step** on the road to reclaiming leadership in Space is to set a firm, overriding goal for Manned Space Exploration, namely the establishment of a **Permanently Manned Lunar Base** that will test out the full range of Closed Ecological Life Support Systems **(CELSS)** leading ultimately to the capability of totally autonomous, Earth independent Homesteads of mankind in Space.

This can all be accomplished efficiently and safely on the Moon, without any need to proceed further at immense costs, risks and potential loss of life. Any discussions of "plans" or "programs" or "missions" beyond such a Lunar Base are smokescreens to deflect from a viable manned Space program. One first has to learn how to take these first steps before setting out to unrealistic, possibly fatal, interplanetary missions. Once this has been set as the driving goal the other decisions follow logically:

16.2. Second: **Upgrade Space Shuttle to 2000 Technology**.

The technology upgrades and choices are clear: the SSMEs (Space Shuttle Main Engines) work great – the major accomplishment of the initial Shuttle RDT&E. What needs upgrading are

16.2.1. **Thermal protection technology:** replace the "tiles" approach with new metallic/composites suitable for routine reuse;

16.2.2. **Thrust assist – replace the solids with pressure feds/liquids**, allowing intact abort, cross feeding, redundancy, and substantially lower transportation costs;

16.2.3. **Continuous procurement of new Orbiters**, allowing thereby the upgrade of US low Earth orbit space transportation capabilities;

16.2.4. **Evolution toward fully reusable Space Shuttle Technology:** as technology and operational experience evolve a gradual evolution toward a fully reusable Shuttle is possible.

16.2.5. **In Orbit Crew Rescue Capability:** this capability already exists with the Soyuz-Shuttle docking capability demonstrated in the 1980s. All that needs to be done is implement it operationally, at little cost.

16.3. **A Reusable Upper Stage (Space Tug):** already a central piece of the 1972 Space Transportation System decision this key technology should now be implemented, including a capability to Lunar Orbit, Landing and Return missions.

16.4. **Significant New Space Science and Application Mission Platforms:** some of these missions have been outlined in the "new" NASA strategic plan, but key applications technology initiatives are missing there from, first and foremost in the information technology areas. Large geo-synchronous platforms – and beyond - building on our Space infrastructure should be a principal component, in applications but also in the sciences.

17. **These goals can be achieved over the next decade and form a real basis for future US manned missions throughout the Solar system**.

More important, the United States will be able to set the historic precedent of a homestead outside Earth, able to, ultimately, function without any support or input from Earth – a true **"Independence Base" -** crucial for the survival and expansion of mankind throughout our Solar system and ultimately beyond.

Everything else is secondary to the Space program, NASA, science and technology: aeronautics, astronautics, life sciences, astronomy and many of the other areas of innovation – important as they are – they would be funded at substantially lower levels than what they now succeed in obtaining as a "fair share" of the Space program, whilst other activities of human exploration might substantially increase.

The rationale – the raison d'etre – of NASA is Manned Space Exploration. NASA seems to have forgotten this and – at least for the past three decades – is meandering around and about not knowing what to do and where to go.

Let us not “burn” our space ships so that others one day will look back in wonderment on how and why the United States FAILED at this historic moment.