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Prospects and methodology for supporting a symbolic Olympian technological duel.

INTELLIGENCE FOR THE SPACE RACE

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A college football coach, spurred by a vigilant body of alumni to maintain a winning team, is expected to devote a great deal of energy to what in a more deadly competition would be called intelligence activity. He must scout the opposition before game time and plan his own defense and offense in the light of what he learns. During a game he must diagnose plays as they occur in order to adjust his team's tactics and give it flexible direction in action. After the game he should be prepared with an appropriate analysis of what happened, both in order that his team may benefit from seeing its experience in clear focus and in order to placate or moderate the Monday-morning quarterbacks. Although both alumni and coach recognize that football has little to do with the true purpose of a college, the coach is under relentless pressure to win games because his team, in some intangible sense, stands for the entire college.

It is much the same in the space race, a game which is similarly characterized by lively competition on the playing field and intense partisan interest among the spectators. In a way which is neither rational nor desirable, our stature as a nation, our culture, our way of life and government are tending to be gauged by our skill in playing this game. Because we should expect to lose as well as win matches in the series, our government must be provided by its intelligence services with reliable foreknowledge of the possibilities for Soviet space attempts and forecasts of probable attempts, with concurrent evaluations of all attempts as they are made, and with detailed reconstructions thereafter.

Foreknowledge and Anticipation

The first intelligence problem is to anticipate Soviet space launches with respect to timing, performance, and effect on world opinion. If such forecasting is reliably done, our own program can be so focused or rescheduled as to be most effective. Suppose, for instance, that one had anticipated the determined Soviet drive to impact the moon which was finally accomplished with Lunik II in September 1959 and had accurately gauged the effect of this success on world opinion. Our planners' negative attitude toward the scientific value of such a mission might well have been softened or alloyed with other considerations in time to make the United States the first to accomplish this elementary feat, which was within our reach also in 1958 and 1959.

More broadly, a reliable foreknowledge of Soviet capabilities and schedules should provide a basis for determining the planned performance levels we should achieve by pushing the development of particular booster and upper stage combinations. A familiar example of frustration in this respect is the discrepancy in performance, as measured by space payload, between the Atlas booster and the Soviet ICBM. This discrepancy is probably correctly attributed to a less advanced Soviet nuclear technology in 1953–55, which required the development of a larger ballistic missile to carry a heavier warhead. But we should make quite sure that in the next generation of space boosters we have no unfavorable balance in mission capability, and one key to settling on the appropriate performance level for this next round is clearly good intelligence.

A third assignment for intelligence in advance of Soviet space shots is essentially a self-serving one—collection planning. This is particularly important for the benefit of ELINT efforts to intercept telemetry data and beacon signals from spacecraft which arc through the sky on unannounced and usually unknown trajectories. Because these vehicles travel around or away from the earth at great speeds, the collecting antennae not only must be large but must be focused precisely on the vehicle's trajectory. The trajectories from the Soviet launch site, however, are remarkably predictable for a given mission, and skillfully programmed digital computers can readily compute the corresponding antenna steering data or look angles with an accuracy adequate to ensure early pickup of the signals.

Concurrent Flight Analysis

Once a Soviet space launch has occurred, intelligence must be prepared to move quickly and confidently into a concurrent tracking, collection, and analysis operation. Prior trajectory computations for a variety of missions and early identification of a particular shot's intended mission can make it possible for most collection sites to pick up the signals on the first pass. This early pickup is critical because only then is the spacecraft sure to be close enough to the earth to be heard by antenna-receiver combinations of standard design; later a capability possessed only by the Jodrell Bank 250-foot dish for long-range listening may be required. A lost opportunity on first-pass tracking can easily preclude subsequent pickup and so nullify the whole collection operation. But when tracking or position data is acquired during the initial phase, it can then be used to refine the prior trajectory estimates and generate more reliable antenna steering data for the next pass, and so on. This bootstrap process is precisely what we have to go through on our own space shots in spite of the fact that we have far more prior knowledge about their intended trajectories and telemetry frequencies. The disparity in prior information means that intelligence, in monitoring Soviet shots, must be even more responsive and skillful than the tracking and trajectory professionals in our own programs.

There is another important aspect to current space events intelligence. Our national leaders are expected to make correct and appropriate comments on each new Soviet space accomplishment. It is unsatisfactory to defer to Soviet claims in framing such comments, and it is therefore the job of intelligence to provide accurate technical facts with great promptitude. Technical information on unsuccessful Soviet space attempts would also be required if it should be decided to comment publicly on this aspect of the competition. If such statements by our national leaders are as authoritative and complete as possible, Congress and the public will be less likely to give undue weight to the rash of scientific but often ill-informed opinion which bursts upon us with conflicting and confusing effect in the wake of Soviet space achievements. A determined leadership well supported by intelligence can assure our national bearing and self-confidence during the times of lost matches which are bound to come.

Post-Flight Study and Reconstruction

Even when the dust stirred up by a Soviet shot has settled, intelligence services still have before them an important set of assignments. Detailed reconstruction of each space mission is essential to a penetrating understanding of the Soviet program, and it provides the only sure basis for technical forecasting. It is also hard work.

A great deal of technical data becomes available to the analyst over a period of several months after a launching from the Tyura Tam complex, but much of it is low-grade ore which can only be compared on a phenomenological basis with similar material from previous shots. Another source is telemetry data, which includes a great deal of valuable intelligence information. In point of fact, the telemetry contains most of the information the Soviet engineers themselves get from a shot. Our exploitation of this unique source, however, is less efficient than the Soviet because, first, we do not know which measurement is assigned to which channel, second, we do not have the calibration or absolute values of readings on the several channels, and third, we do not intercept transmissions covering the entire flight because of radio horizon limitations. Painstaking technical analysis has gradually solved many facets of the channel identification problem and is making encouraging progress on calibration. The problem of early intercepts, to which analysts attach great importance for speeding the solution of the other two puzzles, is one for intelligence collection components.

The technical characteristics of a given shot can be efficiently extracted from telemetry by professional missile engineers who have reviewed all prior shots in detail, and the gross features of a Soviet space shot can usually be thus established within the first few hours by an experienced technical man. The variations and nuances of a given flight, however, which can be equally important, may require weeks of concentrated effort by a team of subsystem specialists working together.

This kind of analysis can eventually give a rather clear picture of mission performance and the technical features of the missile hardware used to achieve it. One striking achievement of such detailed post-flight analysis, the reconstruction of Soviet payload capability, is described in an appendix to this paper as a good illustration of the techniques used.

An important facet of the post-flight reconstruction is trajectory analysis. If one can establish launch time to the nearest minute by identifying fixed events reflected in the telemetry, one can tell a great deal about the mission objective and the techniques being used for lunar and interplanetary missions. For example, the launch time of Lunik I (Mechta) on 2 January 1959 indicates that this "solar satellite" was very probably an unsuccessful lunar hard impact attempt which through a guidance fault went into its fail-safe orbit about the sun. One can also tell from launch date and time whether a minimum-energy trajectory was used in order to maximize the payload or one favoring better guidance was selected at a sacrifice of payload.[1]

It is also important to analyze data from the space payloads themselves. Usually this means telemetry data, which must be correlated with announced Soviet scientific experiments and our own impressions of how particular experiments ought to be reflected on one of the many unidentified telemetry channels. On the flights of Major Gagarin and Major Titov, by exception, we had a source of data in television pictures, which left little doubt about the success of their missions; but it would have been good to know also just how the recoveries from orbit were managed.

The broadest continuing objective in post-flight analysis, however, is to understand the Soviet space program as a whole—past, present, and future. The program in this larger sense is seen as a complete schedule for achievement and acclaim, covering the selection of objectives, the development of techniques, and the exploitation of successes. Because a vigorous Soviet logic almost certainly interrelates these dif-

[1] These deductions really require knowledge of the launching azimuth as well as the launch time, but the azimuth is almost invariably supplied by radar returns, beacon tracking data from radio astronomy installations, or Soviet announcements.

ferent aspects of the program, there is a chance of using the logical relationship to understand and anticipate it.

The Soviet program is characterized, for example, by a sequential attack on prominent space "firsts" in order of increasing difficulty. All resources are poured into a given space objective until it is accomplished; but, except for the biomedical development shots required before putting a man into space, missions are not repeated. Another consistent feature of the program is the remarkably small number of distinct rocket vehicles employed. Every space shot to date has used the ICBM as the basic booster, and the Lunik upper stage has been used versatilely in a number of different roles. The extent of Soviet preplanning and design integration is further illustrated in the adoption of very narrow limits for the firing azimuth for all space and ICBM shots, which makes a heavy investment in tracking and instrumentation facilities along the single range economically possible. This consistency and simplicity, however, gives U.S. intelligence a stable frame of reference for analyzing the Soviet program.

The Outlook

It is well that the formidable task ahead of space intelligence is tempered by a number of simplifications like that introduced by the inherent logic of the Soviet program. There are two other simplifying factors—the undeviating predictability of possible launch times and dates for interplanetary missions, and the costliness of developing a space capability.

The laws of physics and celestial mechanics, invariant in Soviet Bloc and Western applications, impose severe constraints on trajectories that can be flown to the moon and planets. These, in turn, determine the allowable launch times from our spinning launch platform, the earth. The times thus predicted have been found to agree very closely with actual flight data, indicating that tables of possible launch times can serve as useful guides in anticipating and diagnosing Soviet space attempts. These tables cannot tell, of course, on which possible date the Soviets will actually elect to fly a given mission, but they do narrow the range tremendously. They are prepared annually for both direct ascent and coasting orbit trajectories to the moon, and they have been made up for Mars and Venus shots as these missions become possible every 2.0 and 1.5 years, respectively.

The current space race is a duel only, and it will remain so for some time. The small nations may fire sounding rockets in considerable quantity and even launch earth satellites on a cooperative basis, but they are under a strict economic limitation; the capital investment and development costs for a reliable booster vehicle with significant space performance capability are staggering. Only the Soviet Union and United States have thus far undertaken this burden, and they are likely to remain the principal competitors for the next decade. It is an evident advantage for space intelligence that all its collection and analysis resources can be focused on a single target.

The space intelligence problem is nevertheless not only formidable but, unlike most other technical intelligence questions, expanding. A new ballistic missile being developed is of concern and commands considerable attention until its characteristics and the magnitude of its operational deployment have been determined. Once these are established with confidence, succeeding R and D firings assume less significance. Each new Soviet space mission, however, is a fresh flare in the sky requiring a new, imaginative analytical effort. The variety of space missions will expand rapidly as basic capability in space technology grows in both nations. This mission proliferation will probably be accelerated when the Soviets develop new upper-stage vehicles and eventually even larger boosters.

So far we have seen but the first game in a series which promises to be a long and taxing competition. The pace will quicken, and it will increase the popular and executive pressure on intelligence. The prospective consumer demand for successful intelligence efforts suggests that long-term investment of collection and analysis resources is amply warranted.

APPENDIX: DETERMINATION OF PAYLOAD CAPABILITY

The verification of claimed Soviet space mission payloads is important not only because of the competitive nature of space achievements but also because of the possibility of turning payload capability to decisive military applications. We are now in a position, for as long as the Soviets continue to use their basic ICBM as booster on all space attempts, to establish readily whether the payload weight claimed for a particular mission is within their capability. As a matter of fact, one can state in advance the payload capability for a variety of missions they might undertake. This is possible because we now have a rather good model for the performance of the ICBM and the upper-stage vehicles that have been flown with it.

The reconstruction of this capability, a nearly classical solution of an intelligence problem, is of interest from a methodological standpoint. It was characterized by the correlation of unrelated reports from truly independent sources, data computation and cross-checking, several lucky breaks, and remarkable clarity once the puzzle was solved. Unlike many familiar intelligence problems, this had a precision about it in that the reports were generally measurements, the laws of physics provided the correlator, and the solution of a particular case, once it had snapped into focus, was usually applicable to other cases.

Burnout Speed and Lunik Weight

The Soviets had been firing ballistic missiles and space vehicles from the Tyura Tam area for more than a year before we obtained a single measurement that could start the solution process. Soviet payload claims for the first three Sputniks constituted our only sources, and these had to be rated F–6 in the absence of either internal consistency or supporting evidence.

Early in 1959, however, our ELINT sites began to record telemetry signals from both ICBM's and space shots during powered flight. The telemetry format or code was a relatively simple one, and analog records of all channels were readily produced for the portions of the flights that lay above the radio horizon. Several of the channels recorded had evidently conveyed missile velocity and acceleration, data of immediate purport to the performance problem. Ordinarily, however, these intercepts covered only the last 20 per cent of the flight and provided no means to determine the absolute values of the measurements. But during the summer of 1959 abnormal propagation conditions made possible a weak intercept which, with extraordinary effort, yielded telemetry records running from before launch to well after burnout. This intercept, since the total number of digital clicks on the "speedometer," each representing one unit of acceleration, could be equated with the burnout speed required for the free-flight trajectory to the Kamchatka peninsula, established the all-important velocity meter calibration. That was the first lucky break, but it was still not enough, for one had no reliable idea of the weight of any of the vehicles or their payloads.

An absolute measure of weight was soon obtained by a second lucky break. Covertly, we were able to acquire detailed data about the upper-stage rocket vehicle shown in Figure 1, the Lunik stage which mates directly to the Soviet ICBM. Although these data were incomplete, especially with respect to the motor, one could make a good estimate of the vehicle's performance capability by calculating its dry weight against the quantity of normal propellants its tanks could hold. The result checked rather well with the Soviet payload announcements for Lunik I. The stage weighed about 2,600 pounds dry, and it looked as though it would weigh 18,000 pounds with the propellant tanks filled and the payload on board.

Performance Reconstructed

In September and again in October of 1959 the Soviets launched successful lunar probes. Telemetry was received from the powered flight phase of the upper stage, and it was possible to identify this vehicle with the one reconstructed from covert data. More importantly, new long-range radar sets tracked the ICBM tanks which had been used to boost it. These traveled some 3,800 nautical miles on both occasions and hit the water not far from the radar itself.

Here was the missing piece to the puzzle. Had the Lunik stage not ignited, it too would have gone 3,800 miles with the empty ICBM. Since the Lunik weight had been fixed at some 18,000 pounds fully loaded, one could state with high confidence that the ICBM had a capability of throwing 18,000 pounds a distance of 3,800 miles. From these figures we could compute thrust and weight schedules for the basic booster. Having previously determined the calibration of the velocity meter, we could reliably convert this performance demonstra-

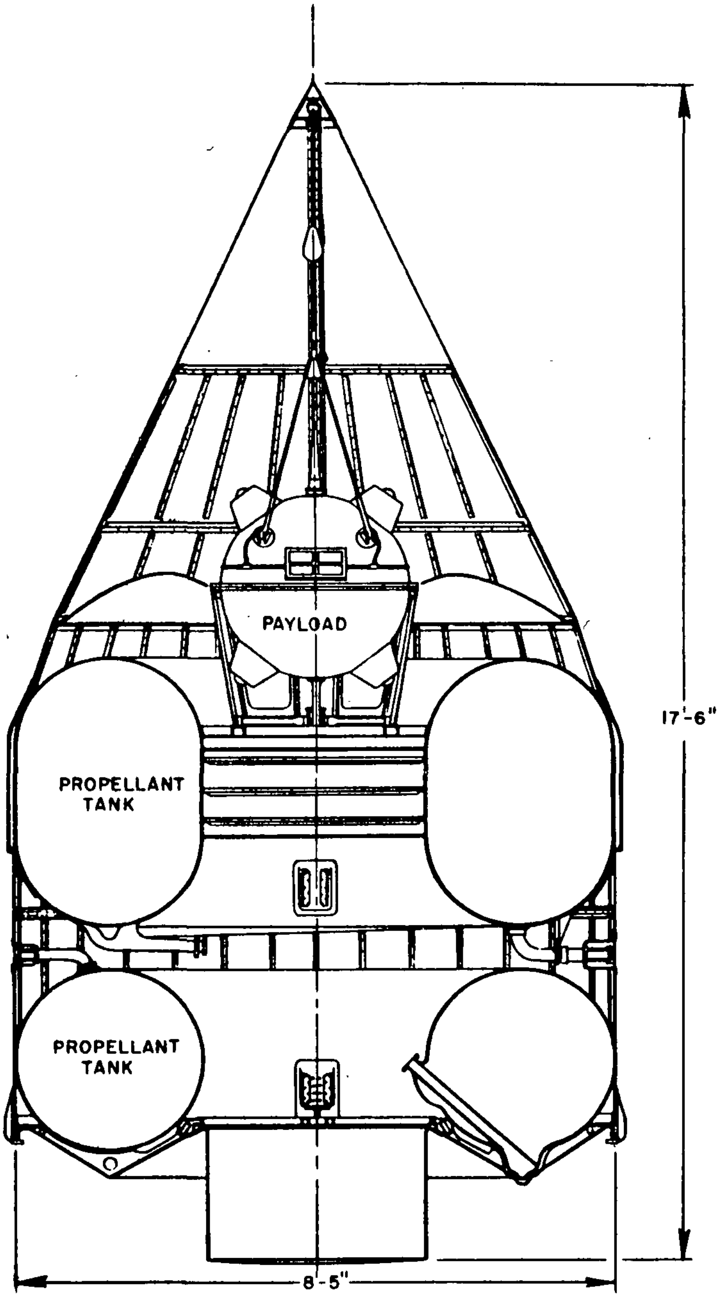

FIGURE 1. INTERNAL LAYOUT OF THE LUNIK STAGE VEHICLE

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tion to other ranges and draw range-payload curves for the ICBM, a result not without significance in another context. Of special importance was the discovery that the ICBM thus reconstructed could place approximately 3,000 pounds into a low-altitude satellite orbit such as that of Sputnik III. This calculated weight agreed with what the Soviets claimed for Sputnik III and tended to increase our confidence in such statements.

For purposes of solving the space payload problem the performance contribution of the Lunik stage had also to be determined—a relatively easy task, for a number of sources bore on it. A velocity meter measurement identical with that noted in the ICBM telemetry was found in telemetry from the Lunik stage, indicating that a common instrument had been employed on the pair of vehicles.[2] Because this instrument had previously been calibrated through our lucky complete intercept from the ICBM, the performance of the Lunik stage could be estimated with high confidence using the empty and dry weights we had established. This checked exactly with the velocity change required to reach lunar escape speed after ICBM burnout as reconstructed from the radar data. The performance of the Lunik stage was thus established with confidence from a number of independent sources. More particularly, the calculation reproduced the announced payloads of each of the three Lunik shots with good accuracy, suggesting both an internal consistency and inherent veracity in Soviet payload claims.

It was no surprise, therefore, when in 1960 the Soviets announced that they had placed an over-10,000-pound space cabin into satellite orbit as Sputnik IV and subsequent recoverable satellites leading up to Major Gagarin's flight around the earth. When telemetry confirmed that an ICBM-Lunik combination had in fact been used to power the cabin into orbit, one could corroborate the Soviet claim with precision: ten thousand pounds was just the payload-in-orbit capability that had been calculated for the combination.

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[2] The same pendulous gyro integrating accelerometer is also noted in telemetry from the 1,000-nautical-mile ballistic missile flown out of Kapustin Yar, suggesting a remarkable standardization.

A comparable analysis was done for Soviet attempts to reach Mars in late 1960 and Venus in early 1961. Although an entirely new heavy upper-stage vehicle was used in these four shots, an analytic effort very similar to that described above led rapidly to the technical reconstruction of this vehicle and of the performance it could achieve in combination with the ICBM. The solution was again accelerated because we had already calibrated the basic ICBM through powered flight telemetry. The resulting weight schedules were consistent with Soviet claims for the (unsuccessful) injector stage in orbit (14,300 pounds) on 4 February 1961 and the payload toward Venus (1,420 pounds) on 12 February 1961.

Missions of the Future

With the results of this technical analysis one can establish reasonable limits for the payload capability of the Soviet ICBM in combination with Lunik upper-stage vehicles for space missions not yet performed. With the vehicle used for the Gagarin-Titov flights, the following missions could be accomplished on direct ascent trajectories with the maximum payloads indicated.

500-mile Earth Satellite	9,000 pounds
Lunar Soft Landing	270 pounds
Lunar Satellite, 300-mile	520 pounds
24-hour ("stationary") Earth Satellite	2,000 pounds

A combination of the ICBM and heavy injector stage with injection rockets firing from a coasting orbit, as in the Venus probe of last February, could perform the following missions:

Mars Probe	1,800 pounds
Mars or Venus Satellite	1,000 pounds
Lunar Soft Landing	800 pounds
Lunar Satellite, 300-mile	1,600 pounds
Lunar Circumvolation and Aerodynamic Reentry	2,100 pounds

If the Soviets were to develop an additional upper stage of high energy, say a specific impulse of 450 seconds, their payload capability for the space missions listed above would be about doubled. If such a vehicle were used as an orbiting injector stage in combination with the ICBM and present heavy stage, the following missions would be possible:

Lunar Soft Landing and Return with Aerodynamic Reentry	500 pounds
Mercury Probe	2,000 pounds
Jupiter Probe	1,500 pounds
Neptune Probe	320 pounds
Solar System Escape	120 pounds

One should note that the communications equipment for probes beyond Saturn would probably weigh more than the indicated payload capability. Nonetheless, it is clear that there is a great deal of mission capability left in the existing Soviet ICBM as basic booster for various upper-stage combinations.

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