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INTERIM TECHNICAL REPORT

BANTAM SYSTEM TECHNOLOGY PROJECT GROUND SYSTEM OPERATIONS CONCEPT AND PLAN

Contract NAS8-97319

Prepared by:

J.M. Moon

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Prepared for:

National Aeronautics and Space Administration

George C. Marshall Space Flight Center

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1. INTRODUCTION

1.1. BACKGROUND

The Low Cost Booster Technology Program, also known as the Bantam Booster program, is a NASA sponsored initiative to establish a viable commercial technology to support the market for placing small payloads in low earth orbit. This market is currently served by large boosters which orbit a number of small payloads on a single launch vehicle, or by these payloads taking up available space on major commercial launches. Even by sharing launch costs, the minimum cost to launch one of these small satellites is in the 6 to 8 million dollar range. Additionally, there is a shortage of available launch opportunities which can be shared in this manner.

The goal of the Bantam program is to develop two competing launch vehicles, with launch costs in the neighborhood of 1.5 million dollars to launch a 150 kg payload into low earth orbit (200 nautical mile sun synchronous). Not only could the cost of the launch be significantly less than the current situation, but the payload sponsor could expect better service for his expenditure, the ability to specify his own orbit, and a dedicated vehicle. By developing two distinct launch vehicles, market forces are expected to aid in keeping customer costs low.

1.2. APPROACH

This document is concerned with the ground support and ground operations system for the Bantam Program. It is focused on methods of performing the system operations in support of a Bantam launch vehicle in a cost effective manner. We are examining two special cases of operations, first, operations during the flight demonstration phase of the program, and second, standard operations after the vehicle enters commercial operations.

2. CASE 1, FLIGHT DEMONSTRATION PHASE

2.1. OVERVIEW

The development flight program will demonstrate the performance of the launch vehicles produced by the two selected Bantam contractors. The intention of this program is not a competition between the vehicles, but rather a pair of flight test programs, with the two vehicles having similar objectives. Vehicle performance data will be collected for the purpose of assisting the manufacturers in their flight tests, and to provide performance information useful for the payload customers in the design of their payloads for launch on the vehicles. This data will include recording of all ground system activities during ground operations, real-time telemetry from the launch vehicle of critical hardware and software parameters, and telemetry collected as available on the payload environmental factors. At the completion of the flight test program it is expected that both vehicles will be marketed to the low cost launch vehicle market by their respective manufacturers.

2.2. FUNCTIONAL DESCRIPTION

The ground support concepts for the flight demonstration program address both the initial acquisition and activation of the launch support and control system, and the routine support of the test flight program. The system which will be developed for the demonstration flights should be fully usable for commercial flights following the demonstration program. The following sections describe necessary attributes of the target system.

2.2.1. Multiple Launch Site Support

Commercial flights are expected to be launched from multiple launch sites. At a minimum, commercial spaceports are being developed in Alaska, California, Florida and Virginia. The Canadians are developing a launch facility at Churchill Bay in far northern Canada, and if the Pioneer Spaceplane option is developed, a spaceport facility will be developed in New Mexico. To support this variety, the ground support system will be either easily transportable or so inexpensive that it can be replicated cheaply at the multiple locations. As of this writing, the system cost goal appears to be 1.8 million dollars for acquisition, including the display and control system and the simulator.

2.2.2. Automation

To meet the cost goal of the Bantam program, a 1.5 million per launch cost, it is necessary to provide support with a small, multi-function team of people which supports all aspects of the ground integration and launch support. Very short cycle times for launch operations are the norm. Actual launch control and support operations in this environment must be highly automated.

2.3. ALTERNATIVE CONCEPTS FOR GROUND SUPPORT TEAM

Traditionally, commercial ground operations have been handled by personnel from the vehicle manufacturer. This is appropriate when each vehicle is viewed as a part of a scientific activity. In order to meet Bantam goals, however it is necessary to treat launch vehicles in a fundamentally different way. The goal is to reach a point where the system is so routine that when a payload comes in you simply go out to the warehouse, grab the next Bantam launch vehicle off the rack, load the payload and launch. The following paragraphs provide alternatives on how the ground support team can be effectively organized and affiliated.

2.3.1. Manufacturer centered

The traditional approach to the ground support team would be for it to be a standard service provided by the vehicle manufacturer with the vehicle. This approach provides a team that is highly knowledgeable about the vehicle. The team oriented operations methodologies described in this document apply directly to this type of team, with the exception that some of the handover points would probably be less formal, and the vehicle integration would likely be supported more by personnel from outside the immediate launch team.

2.3.2. Independent

A second way to establish the ground support team would be to form an independent organization to support launch services for both vehicles. This approach has the benefit of reducing duplication of efforts in forming multiple launch teams. This also strengthens the establishment of common payload interfaces and standard operations procedures across payloads and spaceports. An independent team can be much more focused on payload users and on the aspects of operations which apply specifically to payload operations. Marketing the low cost launch vehicle generically, rather than individual vehicles specifically, may be a more powerful way to expand the small satellite launch market.

2.3.3. Spaceport centered

Another potential method of operations would be for the spaceports to have a dedicated Bantam team for all Bantam flights. This team could support either of the Bantam vehicles, and would be able to gain efficiency through high levels of integration of range safety and range operations. If the ground system is as automated as is envisioned, and given the simplicity of the vehicle, it should not be difficult for such a team to operate. Currently the spaceports do not see this as within their charter, and it appears to be the least likely of the approaches. In the following discussions this option is not elaborated, as it would appear to be costly to duplicate the launch team at each spaceport. It is possible that at some point in the future there may be enough traffic at some spaceports to support such teams.

2.4. STANDING TEAM DESCRIPTION

2.4.1. Rationale

The reasoning behind forming a standing team of payload operations personnel is that a team of this nature will significantly enhance the routine nature of Bantam operations. If the program is to succeed at providing launch services at the target prices, it will do so through a large number of launches. This implies high launch rates, and simple, lean procedures which allow high launch rates. These factors in turn imply a high degree of automation, and a small, (to keep costs down) well trained core of workers to accomplish these launches.

2.4.2. Composition

The assigned members of the operations team will depend to a certain extent on the affiliation of the team, as described above. If the team is employed by the launch vehicle manufacturer it is likely to be smaller, since some of the functions of the team are likely to be assumed by Bantam project engineers. As launches become more routine the numbers can be reduced further.

An independent ground support team would be expected to be composed of a Program manager and a core of operations engineers. The current concept is based on three operations engineers handling up to six launches per year. Each of these individuals will serve as lead for two missions in process, and would be directly involved in supporting all launches. This team would be responsible for all aspects of the launch planning, preparation, and conduct. They will negotiate with the payload sponsor, vehicle manufacturer and spaceport to develop cost and schedule for the mission. They will coordinate all required licensing and mission analysis. They will be responsible for configuration management of the ground support system hardware and software, and verification and management of all delivered flight software loads.

The entire Bantam ground support team will monitor the launch countdown for every launch. The full launch team will encompass range safety personnel, and it will be beneficial to include at least one representative from the vehicle manufacturer to provide vehicle specific expertise during the flight demonstration phase. This is a very lean launch team, made possible by extensive automation of the display and control software.

2.5. GROUND SUPPORT PHASES

2.5.1. Initial ground system activation

For the demonstration phase at least one complete ground system will be developed, and the procedures for operating it will be put in place. The following sections describe the one-time acquisition, integration and verification activities necessary to accomplish this.

2.5.1.1. Operations plan generation

The plans required for running the ground support center will be generated prior to the demonstration flights. Essentially the same plans will be used for the commercial phase of the operations. To accomplish this it is desirable for the ground team to be established early enough in the demonstration program for them to fully participate in early design reviews, and ensure that the ground system is fully integrated into the overall system design.

2.5.1.2. Control Center hardware and software acquisition and integration

Computer equipment, telemetry acquisition and control center hardware and software will be designed, acquired, integrated and tested by the ground support team. The essence of the ground station is a group of workstation based consoles which are either portable or easily transportable to the desired launch site. The option of providing standard outfitting at all sites may be investigated with the spaceports at a later date, but for the flight demonstration phase a single center should suffice, and would probably be most economical.

Software is available off the shelf, and the only significant drawback to existing software system is that they contain features which are not required by the operational Bantam system. Existing ground support software packages are highly configurable, and provide methodologies for automating the launch process to a high degree. They operate in a variety of operating environments, including Windows NT. The primary integration task is to configure the system for Bantam support. The automation required for this program means that the system will have the ability to conduct and evaluate launch operations with minimal external inputs. This in turn requires a significant effort in defining proper systems performance for the software. This modeling and the verification that the model is correct are the primary integration activities for the ground support software.

2.5.1.3. Mockup acquisition and validation

A physical mockup of the vehicle to payload interface will be built during the demonstration phase. This must be maintained and used to ensure that payload interfaces are complied with on both sides, payload and vehicle. This item will consist of a mockup of the mating assembly for the standard payload interface, connectors for electrical power from the vehicle, data connections for the sensor data (this is the one difference between the DFI interface and the standard payload interface) and umbilical connections for prelaunch communications with the payload. This should be a relatively low cost item, less than $20K.

2.5.1.4. Mission Planning Software acquisition and validation

The mission planning system is used to generate flight software for the On Board Computer (OBC) for the specific mission to be flown. This software package is developed by the vehicle manufacturer. During the demonstration phase the manufacturer will be the sole user of this software. The verification of this flight software in operation is one of the prime objectives of the flight demonstration program. Verification of the mission planning system is therefore primarily the responsibility of the manufacturer.

2.5.1.5.Simulation acquisition and validation

The capability to verify that the flight software produced for an individual mission is correct and error free is essential to the long term success of the program. In order to effectively determine that the production flight software load performs as designed it is necessary to test it in a simulator which contains the actual flight control computer or a very accurate emulation of the flight control computer. This allows the ground support team to upload the software (in the best of all cases using standard upload procedures for the vehicle), run through a detailed prelaunch checkout, and fully simulate an actual flight. The output of the simulation can then be used in comparison with the actual telemetry to analyze vehicle actual performance compared to theoretical values. In addition, this simulation will be useful to the ground support team in evaluation of the performance of the system monitoring functions of the control center software.

This simulation is a vital design tool for the vehicle manufacturer, and should be their responsibility to build. Portions of the simulation are relatively simple, since the Bantam vehicle is relatively simple. Flight control computer stimulation or emulation is not simple, and is key to an adequate system. A hardware and software development cost of 830K is estimated. This has been included in the $1.8 million cost mentioned earlier

2.5.1.6. Development Flight Instrumentation (DFI) acquisition and validation

The DFI package is conceived as a standard set of instrumentation to be flown on all demonstration vehicles. This establishes and enforces interface standards, ensures a common set of reference data, and provides a cost savings to the vehicle manufacturers in the area of flight instrumentation. One design decision which should probably be made early in the process is if this package is to be expendable or recoverable. An expendable package must be relatively low cost, simple to manufacture, and still robust enough to return all required data. It would provide an ancillary benefit of allowing small, low cost payloads of the sort many universities wish to fly a "free" ride. Given that this payload would be specifically designed to fly on Bantam it would also have the potential of being the basis for a standard payload package for payload sponsors to use as the basis for Bantam class payloads. A recoverable package can be reused for multiple flights, though it would be necessary to produce backups to account for high flight rates and the possibility of an catastrophic event destroying the entire vehicle.

Data to be collected by the DFI is based on collection rates such as defined in the Low Cost Boost Technologies Fastrac 60K Engine Interface Definition Document. Less than 150 sensor measurements are expected at a 50 Hz rate. The DFI will directly collect data on acoustic, vibration, thermal and structural loads on the payload, and data from additional sensors desired by the vehicle manufacturer. Adding this to the other sensor data indicates that less than 500 data points need to be transmitted at a 50 Hz rate. This is a relatively low rate, and well within the capabilities of economical systems. Additionally it is expected that the command stream generated by the flight control computer(s) will be monitored and recorded for later download. This data is not needed in real time, and it should be easy to recover by downlink from the payload, or directly, in the case of a recoverable payload.

The estimated cost for a recoverable DFI payload is approximately 3 million dollars. To be economical, an expendable payload should cost less than a quarter of that (based on two expendables, and two launches per manufacturer). As the number of launches in the development cycle is increased, so is the total cost of expendable test payloads. Even with this taken into account, it should be realistic to produce an instrumentation package with the required capability for under $750K.

Establishing the DFI as a separate deliverable item is desirable in several aspects. First, it is an ideal item to be produced by a small business, or possibly as a research project in a university. Secondly, it could become a viable commercial product in its own right as the basis for a standard Bantam payload architecture.

2.5.1.7. Configuration management system acquisition and checkout

The premise on which the low cost of the Bantam vehicle is based is that of a launch vehicle which is a commodity. That is, each vehicle produced by the manufacturer is essentially identical to every other. The only difference between individual launch vehicles is the flight software which controls the mission. A well defined method for controlling, verifying and managing the flight software loads for multiple flights is essential. Off the shelf commercial products which can handle this task are readily available. The key factor is compatibility with all vehicle manufacturer systems.

2.5.2. Flight test program

Figure 2.5.2.1 shows a representative timeline for high level ground support activities in support of a demonstration flight.

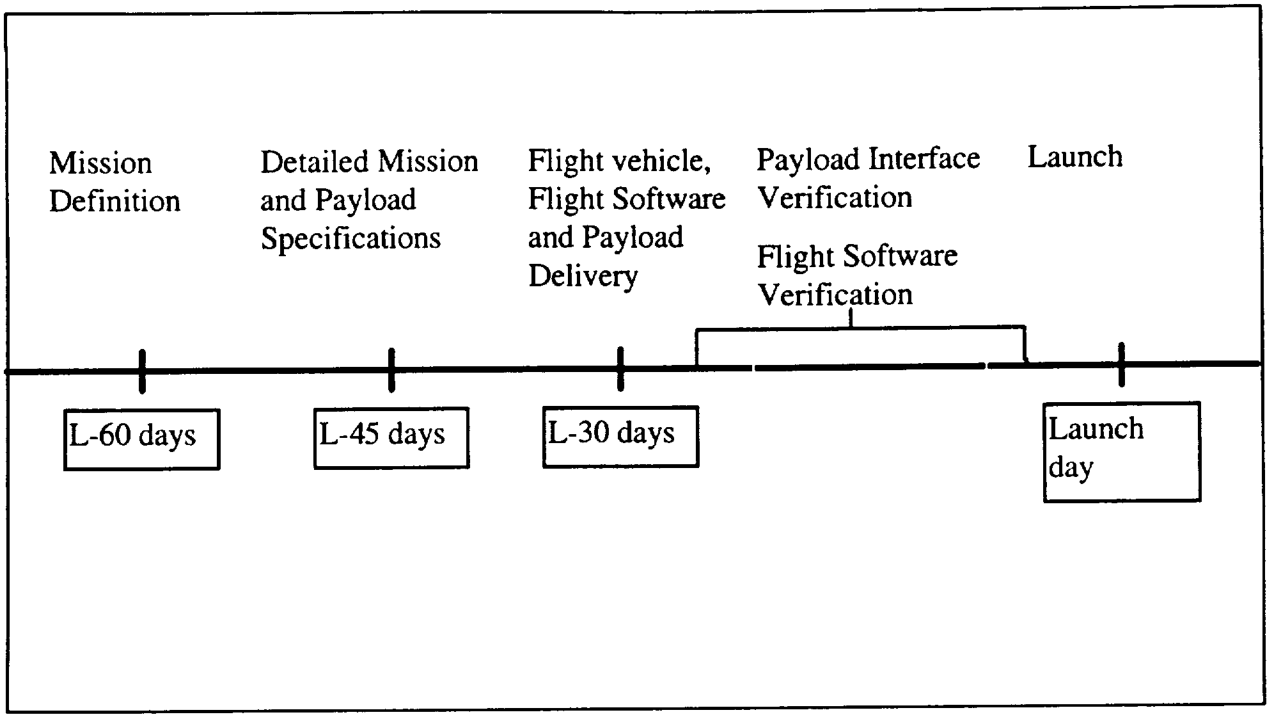

Figure 2.5.2.1 High level mission timeline

The actual flight test program will be carried out to look as much as possible like the expected commercial operation. This allows operational procedures to be developed and validated, and provides essential training for the ground support team. Figure 2.5.2.2 shows the low level processing steps during the launch process.

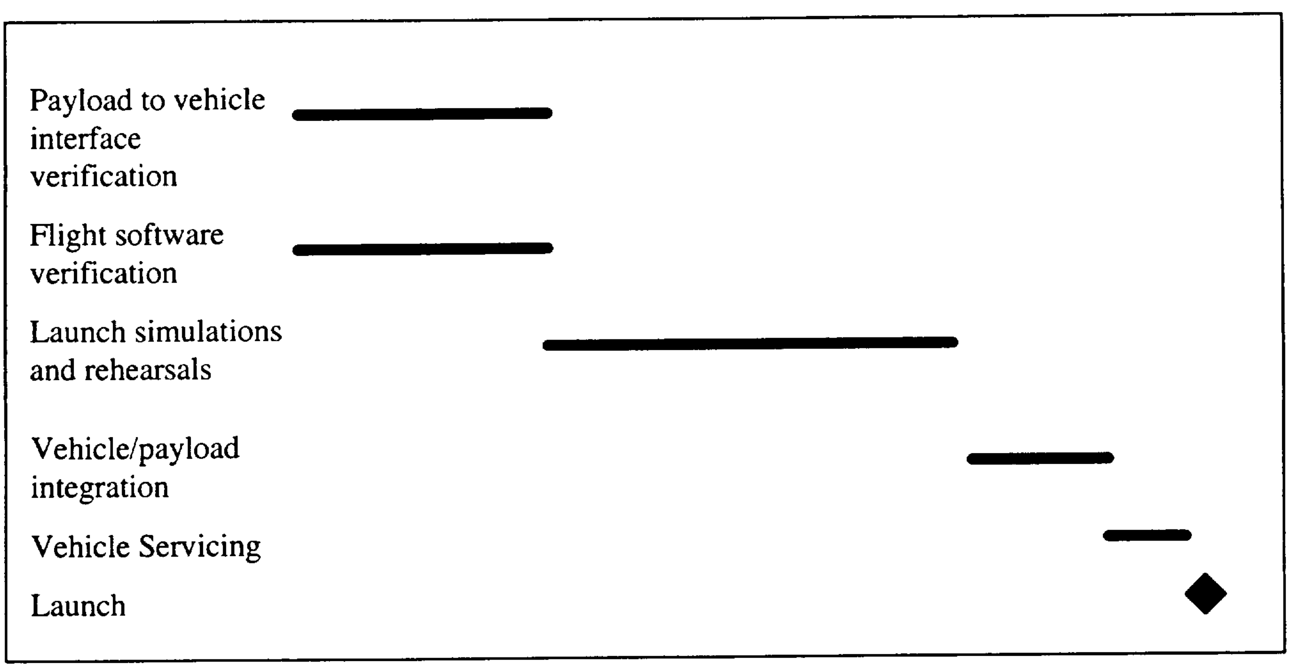

Figure 2.5.2.2 Launch processing steps

2.5.2.1. Mission Definition

Definition of the specific mission details by the customer will be accomplished prior to each Bantam flight. For the demonstration program this data is likely to be available further in advance of the actual flight than would normally be the case in actual operations. The preliminary mission determination and the detailed payload and mission specifications should be available significantly in advance of the actual flight. This data is the input required by the mission planning software system to use to build the vehicle flight software. For the demonstration flights the manufacturer is expected to perform all of the activities necessary to generate the flight software load and deliver it to the launch team.

2.5.2.2. Launch licensing

The vehicle manufacturer traditionally has been responsible for obtaining the license for the flight. During the demonstration program this will be the case for the early launches, but this may be an appropriate function for the ground support team to assume. The expected lead time for licensing from the Office of Commercial Space Transportation is 180 days, but a single license can cover all of the launches in the demonstration flight program.

2.5.2.3. Range safety analysis

A detailed analysis of the flight vehicle range safety considerations will be conducted for each launch, however the initial flight of the vehicle will require an extensive analysis of self destruct capabilities, proposed flight path monitoring and all other aspects of the range safety plan for the vehicle. A significant portion of this analysis is a one time expense, however some aspects of it will be repeated for each flight.

2.5.2.4. Test flight software verification

Delivery of the flight software for the vehicle is expected to be separate from the vehicle delivery. For purposes of software checkout the simulator will look to the ground system like an actual launch vehicle. Software uploads will use the standard interface out of the ground system into the simulator, and the simulation will run a full scenario from fueling through payload release, with the standard ground system monitoring activity as if the simulator were the actual vehicle. The full data recording capability of the ground system will be employed to capture data used for post flight analysis. The essential elements which are tested are the predicted vehicle performance, to ensure that the flight software acts as expected and that the desired orbit is achieved, and the trajectory of the vehicle to ensure safety margins are adequate, and to establish a baseline predicted trajectory for the actual flight. In addition, during early demonstration flights the ground support software is evaluated fully in these simulations.

For demonstration flights the actual verification of the software is likely to be accomplished by the vehicle manufacturer, and collection of data from the flight itself will be a part of the verification of the software during post flight analysis. The simulation will be used extensively by the ground team as soon as it is available for evaluation of software and procedures for simulations as well as ground launch operations.

2.5.2.5. Vehicle/DFI Integration

Integration of the data collection package will be accomplished using the standard procedures established by the ground support team. Vehicle to payload integration for the early demonstration flights will be primarily performed by the manufacturer's team, with the direct participation of the ground support team in the process. This is an area where ground support teams from the manufacturer have an advantage, as they will probably be drawn from the vehicle engineering team. Specific integration procedures will be quite vehicle specific, and ground handling equipment will likely be as well. The most robust expendable system would appear to be a manufacturer furnished transporter, erector, launcher (TEL) which could be used at any of the available launch sites without having to rely on the spaceports to provide the same equipment at each site. The rocketplane approach requires integration of the payload with the upper stage which will provide the final orbital insertion, and an integration of that stack with the carrier plane. Typically this full integration is performed in a hanger type of environment, allowing a great deal of ease in payload handling, and flexibility in integration.

2.5.2.6. Launch servicing

Vehicle servicing is expected to be carried on by spaceport personnel, with oversight from the launch support team. An important aspect of the Bantam concept is to use simple, robust technology. The expectation is that the vehicles will use standard propellants, LOX and RP-1 or liquid hydrogen being the baseline cases for this analysis. This implies that all of the infrastructure, including safety procedures and systems, is already in place at the spaceports to handle uploading fuel to the vehicle. In some cases the spaceports are proposing using servicing vehicles for fueling operations, which would allow operations from a bare pad.

2.5.2.7. Launch

Launch control by the ground support team is a matter of overseeing what is primarily an automated procedure. Once the sequence is initiated the launch control software monitors physical parameters, such as tank pressure and temperature, environmental parameters, such as weather conditions, and verifies proper OBC software execution. Built in holds during the sequence are expected to give the team an opportunity to review the status of all systems, and manual abort is always available. Other than that, the ground control computer will act autonomously, and turn operations over to the flight computer at the appropriate point in the countdown.

During flight real time telemetry may be displayed, and critical health monitoring parameters will be made available to the range safety personnel. The only ground control team function during this time is for mission abort destruction sequences.

2.5.2.8. Data collection

Two major classes of data will be collected during each demonstration flight, real time and on board archived data.

2.5.2.8.1. Real time data

Data collected from the vehicle (and the ground system event log) are archived and displayed in real time. It is efficient and easy to collect the prelaunch operations data this way through the umbilical link. Real time downlink from the launch vehicle is more difficult to collect, and collection adds to the cost of the system in the form of more complex avionics systems and ground telemetry acquisition systems. It is essential, however, that key data parameters be made available for health monitoring from the range safety point of view, and that necessary data for analysis be provided in the event of a catastrophic launch failure. Selection of the key parameters to monitor for anomaly investigation is essential.

2.5.2.8.2. Non-real time data

There is a subset of data which provides information on vehicle performance which does not have any intrinsic real time value, but is key to the final analysis of vehicle performance. Typical data might be detailed information on vehicle bus traffic, vibration information, thermal conditions and g forces encountered during launch by the payload. This data can be collected and written to an on board storage device for downlink on a later orbit, or direct recovery from a reusable, recoverable instrumentation package. Either method allows the real time downlink to be simplified and made more robust, as it will have less demand for high rate data.

2.5.2.9. Data reduction and analysis

Data collected during prelaunch operations, real time launch data and collected non-real time data will be made available to customers, vehicle manufacturers, spaceports, sponsors and other interested parties for detailed analysis. Collected data will be archived electronically and provided as a part of the final program report along with the appropriate analysis. The archive should provide time tagged computer logs of all ground system activity, time tagged raw data stream of all data from the umbilical, and the time tagged non real-time data downloaded from the payload.

2.5.2.9.1. Launch system performance

The non real time data mentioned above is key to post flight analysis for the purpose of defining expected environmental conditions to potential payload customers. The report on this analysis will be prepared and presented as an appendix to the vehicle to payload

ICD. This data is essential to the design of payloads for an appropriate launch vehicle, and can also be expected to be a discriminator for the payload sponsors to use during the selection of a vehicle to launch their payload.

2.5.2.9.2. Simulation comparison and validation

Data collected by the flight demonstration will be compared to the simulation data for improvement of the simulation, and updates to theoretical and analytical models of the system performance.

2.5.2.9.3. Data integrity and security

Two distinct types of data are being collected during these demonstrations, the engineering data to be used by the manufacturers, and secondly the performance data which will eventually be provided to the payload sponsors for use in satellite design. The engineering data could be highly proprietary, and must be protected appropriately by ground system operations. During the demonstration flights there should be no occasion for remote access to the launch control center software, so it will be isolated from the outside. Engineering data will be available only to the manufacturer . The mission planning, simulation software system and flight software will also contain proprietary data and models, so security is an aspect which must be considered in the configuration management and control of these systems.

2.5.2.9.4.Review ground operations procedures and update operations plans

A final review of operations plans in preparation for implementation in the operational phase will be conducted.

2.5.3. Demonstration Program Wrap-up

Products from the demonstration program should primarily be those necessary to support commercial operations. The following should be considered as a minimum.

2.5.3.1.Revise operations plan as necessary for operational modes

Experience obtained during the demonstration flights will carry over directly into operations. By the completion of the demonstration phase there should be a well established set of routine procedures for the ground support system. A particularly important byproduct of the demonstration program is a set of trained ground system engineers. These individuals form the nucleus of the ground support system for the operational program, and they and their skills and knowledge must be retained.

2.5.3.2.Prepare payload ICD and preparation procedures

The standard vehicle to payload ICD is one of the tools which enable the low cost paradigm in the Bantam system. By ensuring a standard interface between the payload and each launch vehicle payloads can be designed to be launched on any available vehicle. This lowers the cost of payload design, and encourages price competition to drive down launch costs. Consideration should be given in definition of this ICD to making provisions for attachment of secondary payloads, which are not supported by the primary payload sponsor, and require only very minimal support from the vehicle.

2.5.3.3. Assist primes in preparation of vehicle performance reports

The operations team will be particularly important in post flight analysis of vehicle launch preparation, servicing and control systems. In addition they can assist in post flight dissemination of telemetry, both real-time and non-real-time.

3. CASE 2, STANDARD OPERATIONS PHASE

3.1. OVERVIEW

The commercial use of the Bantam vehicles is dependent on establishing a new paradigm for space operations. For the Bantam program to be successful the vehicles must be treated as commodities rather than as programs. That is to say, the operation must be made so routine that launch planning and execution have essentially no impact on the program. The launch vehicles from a manufacturer must be so nearly identical that the only vehicle preparation necessary is uploading the flight software and fuel, and the interfaces must be so standard that a payload sponsor can build a satellite and then go out and simply acquire the next (or least expensive) launcher available.

One driving factor in the current world is the cost of insurance. In the Bantam concept, the launch vehicle is so inexpensive that the nature of this cost is shifted. The design of the launch vehicle reflects this emphasis, with importance placed on design robustness, but some degree of uncertainty accepted when it would affect costs.

The expectations of payload sponsors in this concept should be based on the view that cost is the driving factor. This implies, for example, that some systems which would have hot spares in place in today's world, would simply be allowed to delay the launch or not used in the case of failures.

A launch control center in this environment would look very different from today's standard. Instead of rows of consoles, there would be a few workstations. No complicated internal communications system is needed, because all of the operations personnel are right next to each other. Standard, interchangeable PC's or workstations will be used both for low cost and ease of backup in the case of failure. Hot backups and spares are not required in this concept, as potential launch delays are part of the risk the payload sponsor assumes within the low cost launch concept. The display and control system should be stable, with no worry about changes from one launch to the next. The only updates required for a launch are those required to account for the specific mission flight software and trajectory.

3.2. FUNCTIONAL DESCRIPTION

The model for the operational phase of the Bantam system is different from the standard way space missions are currently conducted. Rather than an individually developed mission, each Bantam launch is conducted as a routine activity, with only the actual payload being different from one mission to the next, and the only real difference there is the weight and orbital destination. Unless this type of approach is achieved it will be difficult to meet the cost goals of the program.

3.3. ALTERNATIVE GROUND SUPPORT TEAM CONCEPTS

Essentially the same set of alternative operations teams concepts applies in this phase as in the development phase. The decision on which approach to take is independent of the approach used in the development phase, though this may be interrelated. In commercial operations the independent team approach has some distinct advantages. It allows the payload sponsors to contact a single organization, which essentially acts as an honest broker in negotiating the best launch deal for them. This relieves the payload sponsor of the need to negotiate for the best launch deal. The effect should be to foster a user advocate paradigm, enhancing the competitiveness of the system. It avoids the duplication of having independent teams for each vehicle, making the goal of routine launches much easier to achieve. It enhances the probability that the standard payload ICD will be enforced, thereby reducing design uncertainties for the payload sponsors.

3.4. STANDING TEAM DESCRIPTION

A standing team for launch control allows rapid turnaround for launches, consistent enforcement of standards, and consistent and well defined procedures and methods for continuing improvement of launch control procedures. In the operational era we expect a minimal team, making use of fully automated ground support hardware and software. A basic four person team is envisioned, three operations engineers on the launch team, and a systems engineer with overall responsibility for the functioning of the team. One launch team member would act as the lead for each mission. This lead individual would be the person responsible as the primary point of contact between the payload sponsor and the Bantam operations. This duty would rotate among the team members, so each would normally be responsible for two or at most three missions. As the number of Bantam launches increases operations engineers would be added as needed to retain this basic ratio of personnel to launch missions. The simplicity of the vehicle to payload interface is expected to allow the ground support team to actually perform the physical integration of the vehicle and payload. The hardware to run the system probably must be portable, since it is likely that multiple launch sites will be used, and the cost of outfitting each launch site, and maintaining the software and hardware configurations would be prohibitive.

3.5. GROUND SUPPORT PHASES

Figure 3.5.1 shows the top level mission phases and timeframes for an operational environment.

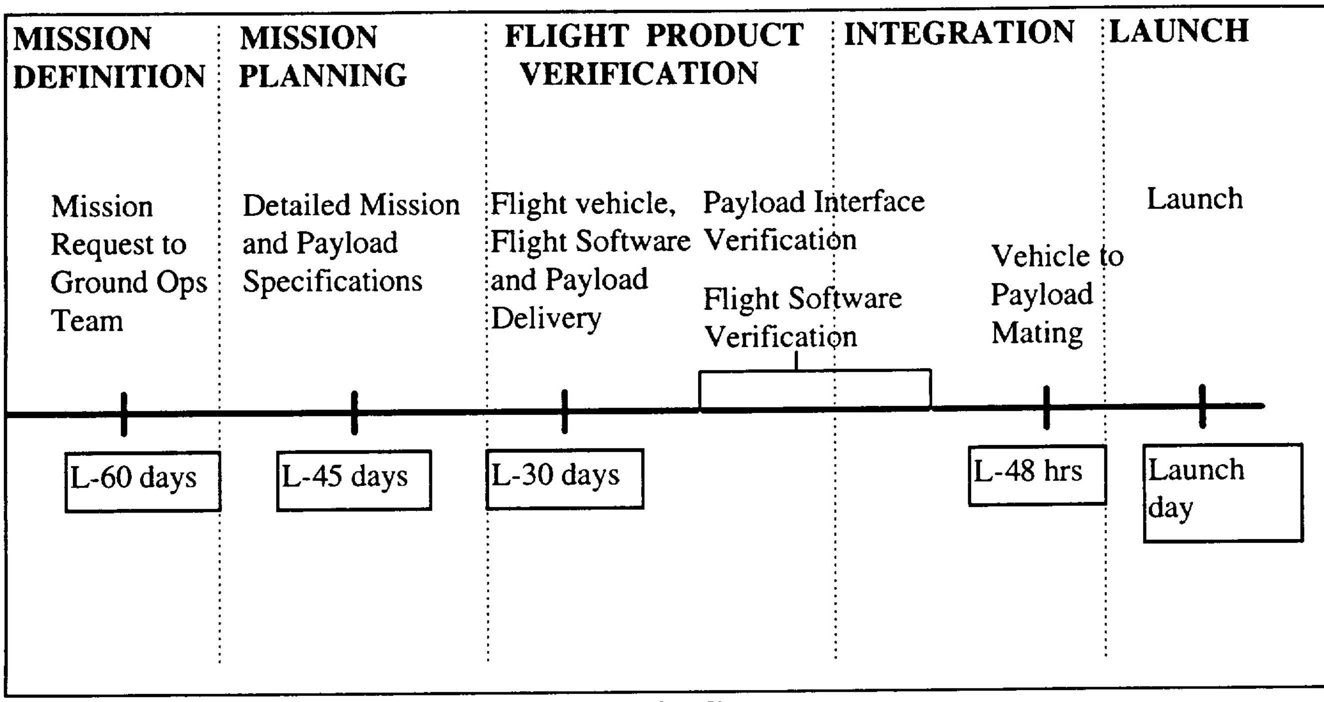

Figure 3.5.1 Operational launch phasing and timeline

Appendix A provides a checklist with specific internal and external activities associated with each of the phases above. The following sections describe these phases in more detail.

3.5.1. Mission definition

3.5.1.1. Request for flight

The initial contact from the payload sponsor to the ground support organization begins the mission definition process. At this time the data required from the payload sponsor is relatively generic, primarily desired orbit, launch date and weight. This is the point at which the scheduling and negotiation begin. In the case of an independent ground team the operations engineer assigned to the flight would initiate contact with the spaceports and launch vehicle manufacturer to determine schedule openings and vehicle availability. In fact, they would likely be working together on a day to day basis, so most of this information would be on hand for the ground team. The operations engineer would initiate negotiation to obtain the desired schedule and best price, along with all viable options. This would be presented to the payload sponsor to select the desired vehicle and launch site combination. In the case of a ground support team integral to the manufacturer the process would be similar, except that the payload sponsor would have to contact both vehicle manufacturers, and they would in turn contact the spaceports. Similarly for the spaceports if they control the ground team, they would contact the vehicle manufacturers for the best deal.

3.5.1.2. Detailed mission definition

Once the vehicle, spaceport and launch date have been tentatively selected, the payload sponsor would be expected to provide detailed data on the vehicle and desired launch parameters to the ground support team for coordination. This package contains all the information necessary to support safe handling of the payload, including information on special handling required, on board propellants, and any hazardous materials handling requirements. The orbital data required is the detail of orbital parameters, weight and any other specific data deemed necessary. At this point in time it may be possible to take advantage of excess booster capacity to fly opportunistic payloads. These are usually small, inexpensive projects, typically produced as course work at universities, which can be flown with major benefits with little or no notice, and only minor support required. The ability to coordinate this type of activity is one of the ancillary benefits of an independent launch team, but this could be done under any of the proposed organizations, if appropriate provisions are made to solicit projects.

Typical time frames for these activities would have the initial contact several months prior to flight and detailed data package delivery shortly thereafter. Licensing has a potential impact on this timeline, however a programmatic license will allow for multiple standard launches with a significantly reduced turnaround. The Office of Commercial Space Transportation has indicated that meeting the anticipated Bantam turnaround should not be a significant problem. In the final expected environment it would be quite reasonable to be able to turn around a payload in a month or less. This assumes that the flight vehicles have already been manufactured and simply need to be shipped to the launch site (or taken out of a storage facility at the site).

3.5.1.3. Optional services

This is the point where desired optional services will be defined by the payload sponsor. Typical optional services we might expect to be requested are:

- Remote access to launch operations via Internet access
- Expanded payload telemetry during ground operations
- Payload telemetry during launch
- Participation of sponsor personnel in integration and launch activities

3.5.2. Mission planning

The detailed information on required orbital parameters is the input for the mission planning process. The primary output of this process is Operational Flight Program (OFP) which executes in the vehicle. In the environment of a standardized set of Bantam vehicles, this is theoretically the only significant difference from one vehicle to the next. Generation of this software could be performed by either the vehicle manufacturer or, if the mission planning software is sufficiently automated, by the ground support team. The mission planning software itself is a byproduct of the development process, and if the ground support team is to run it, it must be procured by them from the manufacturer. The output of this process is an OFP which must be tested, controlled by the ground support team and uploaded to the vehicle On Board Computer (OBC) during preparation for launch.

Due to the high degree of automation expected in the flight planning process and the relative simplicity of the Bantam flight software, OFP generation should be accomplished in a few days at most, so this is not a schedule driver. To support other activities, the minimum delivery time would be 30 days prior to launch.

3.5.3. Flight product verification

The verification of the OFP is essential to ensuring success of the flight. Since this is the only significant difference between the vehicles from one manufacturer, it is also the primary controllable variable between flights. The simulation produced by the manufacturer as part of the development process is the tool which is used to perform this verification in the operational mode. The activities are essentially identical to those carried on during development, except that there is more emphasis on understanding the flight profile for the launch activity, and little or no emphasis on post mission analysis.

The timeline for this activity is short for the actual verification, essentially taking the same amount of time as an actual mission. There may be several simulations run, for familiarization, training and also to benefit payload sponsor personnel supporting the flight (these missions often have an educational purpose which is as important as the scientific purpose of the payload). The month between delivery of the OFP and the flight should give sufficient time to perform as many of these simulations as desired. If there is much impact on the ground support team this may be a chargeable item to the payload sponsor.

The second flight product which must be verified is the payload itself. When it is delivered to the ground support team, they will integrate it with the mockup to ensure that physical, electrical and data interfaces are appropriately configured. A simple electrical and data interface integrity check will be accomplished at this point. As built weight measurements are made for final verification prior to flight.

The timeframe for the mockup testing is immediately after delivery of the payload, one month prior to launch. The activity itself should take less than a week.

3.5.4. Vehicle/payload integration

Once again, the vehicle to payload integration is almost identical to the analogous process during development, with the exception that the data interfaces for the DFI are no longer required. This simplifies the process slightly, but even the DFI interfaces are minimal, so this is not a significant saving. During the demonstration program this function was performed largely by vehicle manufacturer personnel with ground support team participation. For operational launches the ground support team would be expected to perform the actual physical integration as part of their standard activities. Given the straightforward interfaces, it does not appear cost effective to use dedicated personnel to perform these tasks.

Since the payload interfaces were tested well prior to the actual interface to the final launch vehicle, this integration should take very little time. The expected time to begin final integration is 48 hours prior to scheduled launch.

3.5.5. Servicing

There should be no difference at all in operational servicing. The ground support team is in an oversight role during this activity, concerned primarily with ensuring that the Bantam procedures are followed correctly. The ground support team provides the spaceport with the vehicle and payload specific expertise on the launch vehicle. They will become experts in the specific procedures of each spaceport. This is typical of the reason for having a dedicated team, to ensure continuity throughout the launch program.

3.5.6. Prelaunch checkout

Payload requirements for monitoring during ground operations are minimal, so the prelaunch checkouts are less demanding than for the demonstration program. With current launch vehicles the sponsors of Bantam class payloads typically have no ability to monitor payloads flying as add-ons on someone else's launch. Simple health monitoring and possibly the ability to command the payload to a ready mode are all the capabilities which are envisioned.

For commercial operations the recording of detailed data on the progress of the launch sequence should no longer be necessary. The only utility of the data is in analysis of anomalies, and close attention needs to be given to determine if this is worth the cost. Do not assume that this is a free capability just because it was developed during the demonstration phase. Maintenance of the software, analysis of results and archiving data are not free. The key to this question is insurance, and the willingness of the insurance carriers to underwrite a launch without the ability to do a detailed post flight anomaly analysis. Once again the achievement of a routinely successful, high number launch record is likely to be necessary to allow this. In the ideal environment we would consider a "no fault" insurance viewpoint, that is a case where the cost of a replacement launch is low enough and the probability of success on the second try high enough that anomaly resolution is not worth the higher per launch cost.

3.5.7. Launch sequence

During the launch sequence itself events should be the same as for the demonstration flights, except for the absence of the RF link to the DFI, and the noted lack of a need to monitor internal operations. Participation desired by the payload sponsors is uneven, some desire considerable observation and participation, others are only interested in knowing that their satellite is in orbit. The desire has been expressed to monitor launch operations remotely, perhaps through an internet connection. This should be possible at a relatively low cost, however our recommendation is still to avoid even low cost services which do not directly contribute to the mission, as the resultant set of inexpensive capabilities could be significant, and would consume resources which are in short supply.

3.5.8. Post launch activities

The only significant post launch activity is verification for the payload customer that his payload has been delivered to the specified orbit. This may be accomplished by telemetry, ground tracking or any other method to verify orbital parameters. The second question which may be asked is whether the specified environmental conditions for the launch were achieved. This is important in the case of a payload failure to assess the reason for the failure. Once again the tradeoff discussion is the same as it was for launch monitoring, whether the cost is worth the reduction in risk of loss in the case of payload failure. Here the question is if the payload sponsor is willing to accept a higher level of risk to obtain the lower cost. If a significant history of successfully meeting specified conditions can be established during the early operational flights this should be a reasonable request. From discussions with payload sponsors this does not seem unreasonable. In the current state of affairs it costs at least 6 to 8 million to launch a typical payload in this class. A typical payload of this type costs about 1.5 million to produce. As a result the sponsor could in effect buy his own insurance by building and launching a backup payload in the case of a failure, and still be significantly better off than they are today.

APPENDIX A

GROUND OPERATIONS CHECKLIST

GENERAL INFORMATION

The attached checklist provides an overview of the specific internal and external activities during each of the preparation phases for an operational mission.

External Data and Products	Ground Support Team Activities
Mission Definition Phase: Collect following from requester: • Type of payload • Safety considerations (propellants, etc) • Ground handling considerations • Approximate weight • Desired orbit • Desired launch date • Desired vehicle • Requested participation • Optional services requested	Contact appropriate launch sites to confirm schedule availability, and request launch services bid Contact licensing agency for launch Contact manufacturers for bid on launcher Generate price quote for optional services
Mission Planning Phase Collect following from requester: • Exact payload weight (as built measurements will be made after delivery) • Exact orbital parameters required • Confirm launch date • Confirm optional services Mission planning organization performs following: • Generates flight software load and documentation •Performs necessary internal testing	Schedule launch Provide mission planning organization (could be ground support team) with detailed payload data Accept flight software and places under configuration control Perform and document range flight and ground safety reviews
Flight Product Verification Manufacturer • Prepares and ships vehicle Payload sponsor •Prepares and ships payload	Upload flight software to simulation and verify predicted performance • Trajectory • Final orbit • Predicted launch environmental factors Mate payload to mockup and ensure all interfaces are correct Perform simulations and rehearsals of flight as necessary

Integration	Integrate payload and flight vehicle Integrate range safety package (as required) Input mission specific data into ground support software • Predicted trajectory • Applicable flight software checkout data (program checksum, internal performance data, etc) • Servicing data
Launch	Vehicle servicing support Service payload Upload flight software Perform (automated) prelaunch hardware and software checkout • Monitor servicing • OBC test program Sequence launch (automated) • Vehicle launch progress monitor and control data displayed on consoles • Go/no go pauses in sequence provide for manual confirmation • Automated hand-off to OBC for launch • Monitor downlink (if provided)
Post Launch	Obtain and provide payload sponsor with actual payload orbital elements Perform any desired post launch analysis Furnish requested recorded data

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This Operations Concept and Plan focuses on solutions to the requirements previously identified in the "Ground System Requirements" document. It addresses how the requirements will be satisfied in terms of systems and/or procedures. In cases where several potential solutions exist, the alternatives are presented and compared.

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