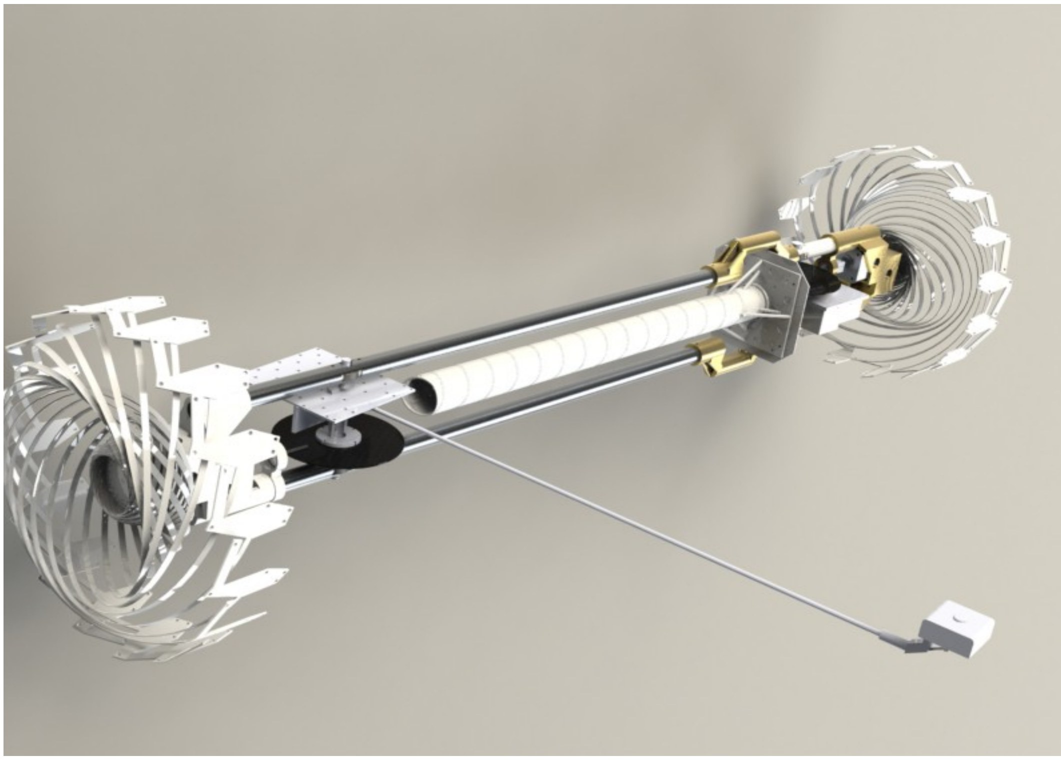
Team PlanB, Mobility Subsystem, Development and Verification Plan



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Acknowledgments

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1.0 Executive Summary

It was mentioned in MS_TRA highlights of the mobility subsystem. Rover included carbon fiber frame, two stepper motors directly controls prime wheels. Two smaller stepper motors control antenna mount and stand for low resolution camera. Power plant consists of storage energy capacitors and solar power harvesting panels. Imagining subsystem of the rover allows choosing the direction and path for a travel, Also imagining subsystem together with mobility subsystem allow verifying distance for landmarks of a terrain. Low resolution of the cameras allows detecting over than 50 meters distances by visual observation. Imaging subsystem components (like low resolution camera stand) designed to be used as additional leg in travel mode. Antenna mound movements can be used to shift center of a mass of the rover to support retracting low resolution camera (for observation picture), and to retract a low resolution camera (to use as additional travel's supporting leg). Navigation of a rover supported by craft gyro-platform (with 2 gyro-sensors, 2 accelerometers and one magnetometer), sets of gyro-sensors and accelerometer (mounted on a antenna's and low resolution camera's stands) and craft's solar sensor with reduced precision after landing and separation from a impact shield. Communication subsystem of the rover consists of the helical antenna and RF equipment operation on 2.4GHz band. Mechanical properties of a rover are equal to a ground station, that allows to test mobility of a rover together with planned test mission on a nano-satellite flight.

2.0 Key items and functions requiring risk retirement.

2.1 Primary mobility actuators

There are a couple of risks with mobility actuators. First one is a unknown performance of a static magnets from a stepper motors under temperature conditions, vacuum and impact from a moment of separation. There are risks that torque of a stepper motor will be less than expected. Usually this risk can be retired by installing gear with ration enough to compensate losses in torque. Two years ago that will be "impossible' to solve task, because gears available was not rated to work under harsh conditions of vacuum and temperature, and custom made gear was not available for financial reasons. Today 3D printing technology allows manufacturing such gear from titanium on 3D printing factory or to be manufactured in-house using 3D printing technology with titanium -silver alloy. Tests on a ground of mobility (performed by a ground station == mechanical equivalent of the rover) require the gear with different ratio. With 0% deformation of the springs of the wheels lunar mobility require 1:5 ratio with torque 0.21Nm, and ground station mobility 1:15 with torque 0.36Nm. Jumps preformed on a lunar surface with gear 1:5 and torque 0.21Nm will be up to 4 cm assumption that time =0.2 sec when string keeps contact with a surface with torque on a stepper motor 0.21Nm. Any deformation of the springs on the wheels reduces lever and make force bigger for same torque.

Pic 2.1.1 mobility for lunar surface with 4kg rover and gear 1:4

	Mobility of the rover on		moon				9.8	1.622			
	N17H118			N17H018		mass kg	acseleration	F=			
Nm=	0.36			0.21		2	1.622	3.244		1.081333	
Dia=	0.27	Radius=	0.135							0.11034	
distance=	0.108	Deformation %=	80	delat deformation=		0.027			load per spring (kg)=		0.108
slope angl=	10	cos(angl)=	0.984808								
gear			1		4						
F=		3.28269251	3.232821	1.914904	7.543249						
F delata=		0.03869251	-0.01118	-1.3291	4.299249						
Presision of measured travel:			Jumps performed by rover:								
acs sens=	0.001			F=m*a							
Dela T=	0.01			a=F/m							
error m/s^2=	0.00001		1.616411	a=	3.771625						
1 sec acs err=	0.001		0.2	t=	0.2						
s=V0*t+a*t*t/2			0.323282	V0=	0.754325						
T=	60		0.82	t jump=	0.47						
V0=	0		-0.28023		0.175383						
s=	1.8		0.41	t/2 jump=	0.235						
		h=	-0.00378	h=	0.132479						

Another methods to confirm on earth a mobility of a rover on a slopes of 45 degree is to use different ratio on the gear and different stepper motor on a ground station's wheels.

Second risk is when rover stuck by obstacle between wheels. For such case 1:5 ratio of a low resolution camera stand can be used to reduce load on both wheels. In this case torque on applied to both wheels allows making a jump with highest point 10cm for 0.21Nm torque, and 27cm for 0.36 torque motor. Flexibility of a camera stand allows having smaller lever than used in calculations 0.5 meter stand. To confirm that risk eliminated (to confirm mobility) on the earth needs to use inclination table and video recording with scale table for jump measurements.

Pic NNN mobility for a lunar surface with 4kg rover, gear 1:5 and assistance from low resolution camera stand length 0.5 meter and gear 1:5 for camera stand.

Third major risk is that rover will not have enough power to perform mobility. That risk driven by small surface area of a rover (where can be placed flexible solar panels). Also harsh conditions of a lunar flight reduce efficiency of a solar cell itself. To fight this was chosen methods when half of the solar panels will be protected impact shield on path to the moon. And rover mobility will allow choosing different sides of rover to perform harvesting energy. Power plant is another measure to solve problem - if rover will be not able to move because of degraded harvesting ability, than it will stay still until power plant will not collect enough. To estimate risk in 2010 was made quick prototype of a power plant with collection energy in high volume capacitor and mobility provided by brief moments with enough power. Prototype was working inside plastic box with low light coming over walls of the box. Constant tests from 2010 showed that energy harvested from 3 square cm is valuable method for support mobility. Low lights conditions allows to run motors of a small rover each 20-30 minutes.

2.2 Mechanisms for pointing, driving, throttling the primary mobility actuators

Mechanisms for low resolution and HD cameras were designed, and prototype was manufactured. All challenges for steps required to manufacture mechanics was overcome. Building materials was chosen - for frame and parts - carbon fiber with special epoxy, withstanding -70+300C and - for gears' parts -titanium - silver alloy.

Changeless in mold manufacturing (for carbon fiber) was overcome. In-house 3D printing facility allows manufacturing most of parts of a imagining subsystem with any complexity of an individual part.

Challenges in manufacturing of molds for bigger parts were overcome by ordering 3d printed models from 3D printing factories.

Time for all technological operations in manufacturing was measured to get estimates of a total time required for mechanics manufacturing

It will be incorrect to the say that imagining subsystem has its own separate mechanics from other subsystems (like landing, or mobility). All subsystems interlace each other and in functionality depend on each other. For example - It is really hard to answer the question -

does the stand for low resolution camera box belong to a imagining subsystem? Or to mobility subsystem?

Challenge for gear designed was overcome. Gears was prototyped from carbon fiber and titanium alloy. Technological operation for creation of gears was measured to be used in estimation of a total time required for manufacturing.

2.3 Mechanisms for deployment rover from craft

Challenges in the development of a laser range finder was solved, with design hardware and software capable of measuring distances 5-25km. Precision for the ignition command of a brake fixed impulse engine was assumed at 0.001s. First, digital to analog and analog to digital convertors were chosen that are capable to work under required temperature operation conditions with a sampling rate at least of 33ns. That sampling rate allows for measuring travel time of the reflected signal from the lunar surface with 10m accuracy. Double paths for laser beam travel allows to measure distances with a precision of 5m. A special sequence sends out to a laser TX module to be emitted over an optical system. This sequence is converted to an analog voltage level signal by DAC. The reflected signal accepts by matching the wavelength receiver, and converting by 8bit analog to a digital convertor value which is stored into a Magnetoresistive RAM. The write operation is synchronized by providing 33MHz impulses to 3 digital counters. That allows addressing MRAM for a light travel time up to 50 km (5Kbytes). A comparison routine scans 5K, to find a match of the same pattern which is sent over the laser beam. To be successful, the match requires performance of 160,000 processor's instructions, with a processor speed 40mln operations / sec. It will be allowed to have 250 cycles of measurements/sec. After the pattern is found and confirmed during sequential measurements, the next second of the flight will be measured with speed precision of 10m/s. That value will be compared to a calculation by mission control and the difference of the speed measured and calculated, will initiate recalculation of the ignition moment. One second before ignition, at a distance of around 8-15 km (2K data to be processed), it will switch to a short scan mode. In this case, the attempt to match measured data transmitted, will be reduced to the "expected" area of comparison (expected 500 byte) and that will increase the amount of measurement cycles to 1000 per/sec. The expectancy delay in the ignition of the engine will be added to predict a last measurement cycle before ignition. After the last measured cycle was calculated, a fraction of mks is to be used to send the ignition command. The command will be sent to ignite the engine and to separate the laser range finder with the attitude control system. That separated chunk ("face-off package") will crash to the lunar surface, but a landing subsystem will perform the brake impulse burn.

Another challenge for the range finder was to use a "test" system where all of these steps would be debugged. A practical way is with the use of sonar equipment to simulate the all of discovered steps. A measuring device was placed in the tank over the surface of water. With the waves simulated on the wrong axis rotation of the craft, different distances were simulated by pumping water in and out from the tank. The averaging/noise reduction pattern search algorithms were debugged on a simulation device.

2.4 Avionics for surface navigation including sensors for the mobility system

Risk that sensors and electronics for data processing can fail because of a temperature conditions and damage by high energy particles was decided to overcome by applying regular thermal stress of all electronics provided periodically.

To reduce risk of damage by high energy charged particles in PCB added patches with special gold layer formed on top of a lead-alloy's half-filled holes. Holes located under the core of each electronic surface mounted component. That will reduce chances of high energy particles, flying from the side of PCB, to collide with electronics' core. From a side of SMD mount, less protection means fewer chances to collide with secondly generated particles produced by original collision of cosmic/sun particles with a protection shield. All SMD electronics component chosen with as low as possible profile to reduce risk of radiation damage, and location of the core of the component analyzed. Basically for a design it means placing additional hole(s) with various diameters under SMD. To reduce risk for FLASH memory damage (or if decision will be made to use magneto resistive / ferromagnetic memory) we have decided to have software and hardware solutions with 2-from-3 majority voting logic for reading of FLASH memories, with simultaneously writing onto 3 memory devices. Software solutions will include software algorithms for majority voting, that solution already tested for 3 different types of micro-controllers selected for a mission. Hardware solution includes additional microcontroller performing such logic on operation read/write for FLASH memory. All 3 FLASH devices will be allocated as far as possible from each other on PCB to reduce chances of damage memory from radiation to a core of FLASH SMD. No tests are planning to verify radiation risk - we simply cannot afford it. Nano satellite test flight should give some assurance, but that risk will be unknown until main mission flight to the moon (not much information is available from public domain about radiation levels).

High risk that solar sensor will be clogged with dust and will be not able to find direction to the sun, was decided to overcome by applying software solution in mobility. Special shaking movement needs to be performed to shake-off dust from hole with solar sensor. That movement is easy to perform - study rotation will be applied to a frame of the rover when antenna and low resolution camera stand are in travel position. Sudden stop will shake off dust from a sensor hole.

Risk that random path movements to avoid obstacles and "left-direction" avoidance path both can fail to find a proper path cannot be eliminated - for such case still picture needs to be taken on each attempt to move to a different direction and delivery of a picture to mission control

2.5 Hardware and software for distance verification, including any on-ground processing steps.

Risk that it will be not enough time to transfer all mobility recorded data in a communication session was decided to overcome by adding into a software capability to increase speed by grouping packets before switching frequency. It is solo software but it can increase speed transfer 2, 4, and 8 times. But overall risk can be related to low power energy harvested. That risk cannot be eliminated 100%. Was decided that in this case assumptions based on recorded by accelerometer measurements can be used as backup method for distance verification.

Also was decided that same solution (to obtain accelerometers records) will apply to mitigate the risk.

2.6 Lunar communications

Risks of failure lunar communication system was solved by investigating each chalange visible for that vital subsystem.

A challenge was solved in developing in-house proprietary RF communication equipment. Design and manufacturing steps were analyzed with the time for manufacturing measured.

Communication will be over unlicensed frequencies bands at 2.4 GHz (no limitation on antennas design, different limitations on max power in different countries). Operational steps and technologies were measured to be communication subsystem flight certified. Issues were solved in matching the impedance of transmitter, receiver and amplifiers. In 2012, a selection was done out of the available power amplifiers and LNA. Two versions of the communication system were developed. The second version used an "AT" modem implementation at one layer of a data transfer protocol. The challenge with the complexity of a supporting error correction on the top layer (up from modem protocol) was solved by abandoning the use of an "AT" type modem. In development, there is now a third version of the software. The source code was ported to all possible micro-controllers. This supports having an extended hardware implementation for the ground station with a capability to log all that is received from the craft/nano-satellite communication packets to a mission control database. Challenges in the integration with ground station and mission control were solved. These included (a) transfer of encrypted data to a mission control server, (b) design, development, and verification standalone HTTP server as a ground station communication hub, (c) synchronization time between Mission control server, ground station communication hub, communication micro-controller and (d) logistics for range tests for 1.7km, 4km, 25km with 0dBm transmitting power.

A solution was found for the deployment of antenna to have a gain of no less than 16 dBm. This was solved by prototyping 4 antennas: (a) helix with 16dBm (b) deployable for nano-satellite 6dBm (c) low profile reduced polarized helix >18 dBm (d) low profile deployable reduced polarized helix > 12dBm. Certificates regarding the techniques for manufacturing flight nano-satellite and rover antenna were verified. Manufacturing techniques for the ground station antennas were also verified. The challenge around the ground station manufacturing antenna was in the low precision of 3D printed parts. Long antennas were not stiff enough. As a result, it required a special 3D design to support the structure. A polarized version of the helix has to be precise with 0.1mm, otherwise all advantages of a polarization (transmitted energy will be polarized and gain will be improved) are not solved yet.

The delivery of data over noisy environments, or over long distances with low transmitted power, is a constant area for solutions and improvements. Doubling and tripling the communication channels, is a usual choice. But with any increase of the transmitting channels, the data restoration numbers become challenging due to possible de-synchronizations. Delivered packets can be perfect, but timing of the events can ruin the tripled sensors reading with full flight lost. Sequential tripling was implemented, with each packet transmitted over the first, second, and third communication channels, one after each other. Preamble was increased and the address field was equal preamble. Each packet arrived to ground station, with mandatory storage in the mission control DB for a future possible restoration. Restoration of packets with broken CRC was done by complex measures including shifting data and majority voting 2-from-3. Precision of the channel's switching was done by stabilizing crystal with temperature operational condition of -40+125C, and software algorithms with adjusting switching time. The frequency drift had to be compensated because of different temperature operational conditions on the craft/nano-satellite and on the ground station. Constant adjustment processes were implemented during the communication session and the initial session's adjustment process, when the ground station tried different channels with craft/nano-satellite listening on one frequency.

Challenges in transferring data from/to different layers of communication protocols were found to be a critical process. On the communication device, exchange algorithms were implemented for data synchronization stored externally for micro-controller FLASH memory.

The challenge with precisely measuring distances from the ground station to craft/nano-satellite was solved by selecting stable crystal for the micro-controller, and routine to load "loop" message with measured data.

The challenge to deliver an "extreme" power burst from the ground station to the craft on trans-lunar trajectory was solved, by design swappable technology for ground station antenna. Instead of 1 antenna on the ground station, for the main mission four can be mounted. The simplification of a winding 3D printed antenna, allows updating amplifiers for the helix in 1 hour and for polarized helix for 4 hours (on a ground station).

2.7 Thermal control subsystem of a rover

Challenges for temperature measuring technique were overcome by software design, implementation, and debug. Software work with DS1822 sensor with accuracy of temperature measurement +-2C in -55C +150C interval. Sensor has special interface to communicate with multiple device over same power and data line. Numerous micro-controllers can do all measurements. Special measure was applied to all software development to optimize number instructions executed by micro-controllers. Each instruction executed by micro-controller mean additional power require by power plant. Challenge to work with different architecture of micro-controllers was overcome by producing source code portable to different platform and compilers.

Challenge for thermal control study for HD camera box and low resolution camera's box was done by experimenting on extrudes system of 3D printers. Different technique was tested and adapted to design of software (for supporting active camera's thermal control). For "on moon" mode of a thermal control was chosen additional temperature sensor located on the tip of a camera box. That additional sensor solves challenge for thermal control with use of lunar regolith as a source for heat or cooling.

2.8 Challenges in interfaces to other subsystems.

Challenges are constant in software development. Software was considered as a main tool that can help to solve hardware challenges and to eliminate challenges in mission itself. A lot was solved and still are waiting to be solved on the way to the moon. First, was decided to do not follow any standard methodology in software development, as all methodology designed to increase costs of development instead of concentrate on the goal. Second, was abandoned any standard protocols and API interfaces for a communications, instead was chosen serial and I2C protocols, and "state machine" for instructions/commands processing. For real time processing the date was considered technique with interrupt hardware support in micro-controllers, pipes support for data, and call backs functions provide interface. Challenge for transferring data from imagining subsystem to a mission control was overcome by rapid designing, open implementations, and debugging procedures with automatic testing. It is hard to say which software belongs to a communication or to a imagining subsystem, source code for all micro-controller with different architecture shared. That allow in matter of week to change type, computing power, and power consumption of all electronics in imagining subsystem. Solutions in a software interface for imagining subsystem, benefits communication subsystem.

Sample of successfully solved challenge is a gyro-sensor and accelerometer used in imagining subsystem interface. Gyro-platform for a craft or nano-satellite used two compensated gyro-sensor and accelerometer. The same software but compiled to work with one gyro-sensor and one accelerometer used as add-on to microprocessor controlling movements of a camera's stand, and antenna mount (it will be also correct to say HD camera box mechanism.

From another challenge in software development of a gyro-platform was a hard task by itself, even all formulas for quaternion mathematics, and Kalman's filters was well known, but real, fast, implementation, with less as possible instructions required for date's processing was required enormous amount of verification in calculations.

On high level imaging subsystem keeps its data (picture/video) in FLASH memory (micro SD memory card with operational conditions -40+125C). Challenge to protect that data from damage by high energy particles, was solved by keeping that data in three separate FLASH devices, with physical location as far as possible from each other. Write operation are performed simultaneously to all 3 devices and read based on majority voting 2-from-3.

Challenges also were to develop tools for testing of a sealed box with HD camera with helical antenna in in-house vacuum chamber.

Developed technique for incorporation of from-shelf HD camera to be adapted to work on rover/nano satellite. That challenge solved, time for incorporation measured to be account in total time calculation for manufacturing rover/nano-satellite.

Technique for laying protection layers of urethane for low res camera tested, it was not considered as a challenge but rather development task.

Protocol for retrieving data and making low resolution picture by low resolution camera was designed; implemented and verified, interface for mission control was tested.

Challenges was solved for rapid prototyping and manufacturing of all electronics in-house. That was done to make guarantee that manufactured electronics will pass outgassing tests, and will work in vacuum and temperature operation conditions.

Challenge raised by a long schedule asked by launch providers and delays was overcome by abandoning "frozen design" ideology. All nano-satellite designers after private conversation confirmed that delays will be from 1 to 2 years from conformed date of launch. In that period of time technology in manufacturing, electronics, software will be obsolete. Instead of "sketch-up" design was used as a prime method. Equipment, hardware, electronics components, software technique should be investigated, tests to incorporate new hardware/software into all system (mission) was performed, time for implementation and manufacturing hardware/software was estimated, but manufacturing of full hardware can be postponed till "where is your cubesat?" question asked. One of the samples of that type of challenge was orbit determination subsystem. As one of the tools to detect direction to the earth, in 2010, was considered imaging subsystem. Picture taken by low resolution camera can be analyzed, edge can be detected, and direction to center of the earth can be calculated. Special image sensor with good temperature operation conditions was chosen to process gray scale picture. Black and white sensor was sensitive in 720nm and capable to detect starts with apparent magnitude 1 or 5. Those capabilities allowed detecting earth edge on night side of the orbit. Software to convert image to jpeg was ported to microcontroller (jpeg was a deliverable format from imaging subsystem). Technique to detect earth age by projecting unparalleled lines was tested on gray scale picture on PC, formulas implemented to pinpoint position to the center of circular body. All was done to find that imaging sensor was discontinued from manufacturing; substitution was not even close to parameters of obsoleted sensor. As a result imagining subsystem's requirements become "lighter" from functionality. In a middle of 2013 different sensor (now color with temperature operation conditions -40+105C) was appeared on market. That opens back opportunity to make imagining subsystem little bit smarter, than to take just a picture and to deliver it.

3.0 Tests and demonstrations to retire existing risks.

There are group of measures which will be required to retire risks. That includes different studies of a mechanical parts, software, hardware, tests/measures will be performed regularly, and/or on demand.

Test which performed daily/weekly:

3.1.a) daily software tests to verify that added functionality is working, old functionality did not broken, and removed functionality kilted for records. For that tests development process organized to split any software changes/implementation into a 1 day frame. Each added / changed line of code hast to be "stepped" in debugger. Compiled code analyzed on instruction's level. Test scenarios with external measurements / indicators created. Units are tested by implementing test's cases on a PC with serial communication connection to a testing unit.

3.1.b) Mechanical’s part and electronics hardware exposes weekly to a vacuum <1 Torr and 125C degree for 30 minutes. After cooling to 25C degree it exposed to -5C for 8 hours. Monthly added test - after cooling (from vacuum test) hardware exposed to -75C for 3 hours.

3.1.c) In manufacturing carbon fiber parts technological procedure conformed to follow curing process requirements.

Special test performed on demand-

3.2.a) range tests for communication 2km,5km,25km

3.2.b) vibration tests 0-15 Hz for assembled mechanics. Duration of the test is 20 min.

3.2.c) drop/shock tests for assembled mechanics Duration of the test is 20 min.

Tests for assembled components. Requires additional verification procedures. Planning.

For assembled rover and nano-satellite planned weekly performed vibration tests. Frequencies 0-200Hz. Also are planned acoustic study stand for detecting resonance frequencies 200-5000Hz. That acoustic and vibration test not only for an assurance of mechanical integrity but mostly to confirm that short marriage of a craft and launch vehicle will be not destructive for both sides. Those tests usually performed on third party facilities. And some time launch vehicle owners do those tests by themselves. To pass acoustic and vibration tests needs to have daily available in-house tools which can help to prepare assembled craft or nano-satellite for tests. Basically acoustic test is a loud expose to a sound (139dB) frequencies applied to a testing assembly. It is impressive by it noise. Instead of this we consider to have in-house a stand, where regular sound, with variable frequency, will be applied to the object and sensor can detect vibration, which will be indication of the resonance frequency. In-house vibration table for a frequencies 0-200Hz is also essential part to detect problem in assembly and to verify mechanical integrity. For assembly it is important to perform shock tests. Shock usually come as a result of divorce process, after short-time relations between launch vehicle and mounted on that vehicle craft. Process is unpredictable in our case, to consider that main mission will be a flight as secondary payload. Payload adapters/ Mechanical Lock System/ Mini-satellite Separation System/ Pyro locks (which keep craft still inside payload compartment) will depend on shape and attitude of its "comrades" from cargo bay. Marriage of a craft with launch vehicle was done usually by various pyro-devices, and separation was done by explosion of pyro-component and braking bolts. Each fully or partly assembled object better be testes right away for such stress. We consider having pneumatic shock testing tool to perform such test on demand.

All this will require 3 additional stands to have in next year to retire risks in assembly and development of a craft.

3.3.a) Tests on vibration table. 0-200Hz. Performed in-house. Duration the test is up to 20 min.

3.3.b) Acoustic study stand. 200-5000Hz. Performed in-house. Duration of the study expected to be 1 day.

3.3.c) Shock pneumatic tests. Performed in-house. Duration of the test 1 minute.

3.3.d) Nano-satellite deployment box will be manufactures to perform vibrations tests on nano-satellite.

There are also tests which we are planning for retirement of technical risks on near future. Those tests can be considered as "demonstration tests", because they will be indicators in a process of readiness of hardware for a main and test mission and also can attract our funs as “milestone” event.

3.4.1 Communication range test (25km) Rehearsal demonstration. One ground station will be located in Stanley Park, Vancouver (or at another place can be considered) and Nano-satellite assembled in Simon Fraser University park (requirements for both location is 25 km of visual site). Nano- satellite will be suspended on a wire to allow free rotation in horizontal plane. To the left and to the right from suspended nano-satellite will be objects representing (a) earth edge visible from LEO and (b) moon. In demonstration (controllable from mission control server) nano-satellite will determined its position and velocity by analyzing row signal from global navigation system. Nano-satellite will report that data to a mission control via backup communication system (via satellite communication). Mission control will calculates the orientation direction for antennas on nano-satellite and ground station and send orientation’s commands via backup communication to nano-satellite, and to ground station via IP connection. All calculation will be with assumption that nano-satellite orbit is equal to the circle and with period of 24 hours. On nano-satellite will be calculated direction to a center of earth by accelerometer and the direction to North Pole by magnetometer. Both antennas on a nano-satellite and ground station should turn to point to each other.

Visible movement will be indication of correct performance of such event. Next will be the attempt to establish communication session over noisy environment over Grate Vancouver. Non-noisy path can be chosen as alternative for the 25km test. Planned transmitting power on nano-satellite will be 0dBm(1mWt). Planned transmitting power on ground station will be 0dBm (1mWt). Different transmitting power can be chosen in the test up to 30dBm(1Wt), without exceeding max allowed in Canada 36dBm(4Wt) for 2.4Ghz Frequency-Hopping Spread Spectrum systems. After communication session establishment from the mission control will be send commands to orient nano-satellite to the a exposed object representing edge of the earth (picture) and object represented the moon (another picture). After two orientations turns two pictures will be taken, and nano-satellite will orient itself for a next communication session. Time of session will be provided at previous session. Then second communication session will be established and mission control will be able to retrieve low resolution and high resolution pictures. On third communication session it will be request to record 1 min HD 720p video. Session # 4 will be for a retrieving HD video to a mission control. Then ground station will be assembled to have "rover" configuration and placed on inclination table with 1/6 of the earth gravity and with ability to point antenna to earth located Stanley Park. Session #5 will be provided to confirm functionality of a ground station in rover configuration. Last will be command which will be send to a ground station (rover) to retrieve low resolution camera's box and take a pictures. In that case picture will be delivered to a mission control without RF communication. "Rehearsal" test duration time is 2 hours.

3.4.2 Rehearsal up-side-down demonstration test. All electronics for the nano-satellite is equal to electronics on rover. Deferens (if will be) is in software. As a result rehearsal demonstration test 3.4.1 any time can be switched to "up-side-down" when nano-satellite performs functionality of a ground station, and ground station can be tested as remotely controlled rover. In this case mobility test of the rover can be performed with mockup of a lunar surface. For best regolith simulation will be used rye flower, for rocks and craters can be done quick made mockup from available material, dusted with rye. In this test all “broken” mechanical / electronics hardware can be tested, functionality for reduced functionality of a rover and imaging subsystem can be verified.

3.5. Communication range test (min 100km) demonstration - the same as in rehearsal demonstration 4.4.1 test but two points in BC(or BC + Washington) mountain range will be chosen to have 100km tests. Transmitting power in the test will be 30dBm (1Wt), with attempt to reduce power to 0dBm on both transmitters. Duration of the test the same as in 4.4.1 test.

3.6.1. Vacuum (<1Torr) chamber test/demonstration (with nano-satellite inside) and all systems are working, This test similar to test #1 except transmitter power will be 0dBm and orientation of a nano-satellite will be conformed visually, all picture and video (inside surfaces of the vacuum chamber) will be taken. From a mission control, starting from second session, parameters of the orbit will be faked to a real satellite orbit flying over Vancouver in time of test. That fake orbit's settings will force antenna of a ground station to orient it into a direction of a real flying satellite. Second HD camera, mounted on an antenna stand (different observation angle than designed for a rover), by commands from mission control will be able to record parch of sky with flying over real satellite. For that test needs to choose proper time at the evening or at the morning for a visible (recorded) conformation of the orientation (attitude), and mobility subsystem. Vancouver weather needs to be taking to account at this test. Duration test's time approximated to be 2 hours.

3.6.2. Test the same as 4.6.1, but in vacuum (<1Torr) chamber will be a rover (ground station) powered by its power plant and nano-satellite will be switched to work in a ground station mode (all electronics hardware on rover and nano-satellite are equal). Rover will be inserted to a vacuum chamber without wheels, and gears. Energy storage of a power plant (high volume capacitors) will be charged to a maximum level. Will be checked performance of a power plant with a task performed by imaging subsystem.

3.7. Test of a thermal subsystem of a nino-satellite - the same test as 4.3.1. Instead of vacuum chamber will be nano-satellite suspended on wire supporting free rotation. Nano-satellite will be placed between heat element (+80C) and cooling container (-75C). Outcome of a test expected to be the same test as in 4.3.1. In this tests thermal control subsystem should calculates best directions for cooling and heating and perform autonomous orientation maneuvers to heat and to cool overheated imaging subsystem parts.

3.8. Test with fully equipped rover with impact shield will be dropped from 70 m (around 24 floors of the modern buildings). Before test, control communication session will be established with mission control. HD camera of imagining subsystem will be switched to record the landing video. Rover will be rotated on a suspension support before drop. After impact rover has to be established communication session with mission control to delivery HD video of landing test. Adoptive filters will be placed on solar sensor to simulate earth position by sun. On landing point will be placed box with simulated lunar regolith. For lunar dust will be used rye flower. Test will take 2 hours and time equal 1 min HD video transmission.

3.9. Certification outgassing vacuum test of nano-satellite. It will be flight to Ontario, to test facility. Testing nano-satellite will be placed into vacuum chamber, exposed to vacuum 1x 10-4 Torr, applied heat to nano-satellite till it reached 70C, wait for 3 hours with recording pressure value inside chamber. Duration time is 4 hours. Filming will depend on a permission of the owner of the facility. Results expected - the pressure records will be passed to a launch vehicle provider.

3.10. Vibration and acoustic test, for certification of the nano-satellite to flight (for test mission) will be performed on in-house vibration and acoustic test stand. Resonance frequencies for nano-satellite will be documented and passed to a launch vehicle provider.

3.11. Vibration and acoustic study of a craft's mock-up. All parts of a craft will be manufactured. Special mockup of fixed impulse engines will be manufactured. To have the same exact weight of a fixed impulse engine, into mockup will be filled wax, nozzles will be 3D printed from titanium. The same test as 4.10.

3.12. Flight-to-ground test. The same as test 4.4.1. Nano-satellite will be on the orbit. When it will fly over ground station, ground station(rover), based on information from mission control has to track nano-satellite on a sky, and communication session will be indication of a successful mission. In subsequent sessions pictures will be taken and video will be downloaded. It is planned to use 2 ground stations one in Vancouver another Langley/Donetsk.

3.13. Certification outgassing vacuum tests for a rover and impact shield. The same test as a test 4. 9.

3.14. Certification vibration tests for fully assembled craft. Probably will be done at facility provided by launch vehicle provider.

3.15. Test for laser range finder system, has to conform functionality of a laser range finder on 1km, 2km, 4km,10km, and 25 km range. Flat cliff like surface has to be selected to perform such test in BC mountains. Test to be performed under diriment lighting conditions at day and at night time. BC provincial campground will be booked, shashlik and slipping bags will be provided

3.16 Tests for all pyro-devices with separation frame and mockup fixed engines will be performed and the process of separation will be analyzed. This will include individual tests of each frame connection mechanism and all of the mockup craft. For the nano-satellite, such a test is not necessary because it is not allowed to have any pyro devices on board. Instead of this, the nano-satellite's deployable antenna is released, by burning nichrome wire in the lock mechanism

3.17. Brake engine parameters tests. Manufacturer will be asked to verify parameters of the brake engine and the test will be performed on the manufacturer facility.

3.18. Gyro-platform calibration. Measurements on the performance of the gyro platform will be recorded and decisions will be made to either accommodate existing precision, or to use second gyro-platform to improve twice the precision.

3.19. Assembly of the rover and ground station verification torque tests. Those tests will be performed after each assembly of mobility subsystem. Torque will be measured to conform values required for lunar (or for ground station for earth) mobility.

3.20. Rye flower tests are the tests required to conform shaking algorithms movements. Dusting box with a low resolution cameras and solar sensor are the tests to be performed in mobility software development.

4. Development, verification and integration steps planned for the mobility subsystem.

4.1. Manufacturing of all carbon fiber parts for testing mission of nano-satellite flight needs to be done.

4.2. Assembly of nano-satellite together low resolution / HD camera has to be done.

4.3. Incorporation of a final version of electronics' hardware for low/high resolution and video capabilities has to be done with all subsystems of nano-satellite. Hardware will be designed in-house, PCB manufacturing by order, soldering will be done in-house. Full circle between incremental hardware versions is estimated to be one week.

4.4. Hardware vibration tests, and acoustic tests on assembled nano-satellite needs to be performed - that will include in-house tests and study, and certification tests on separate testing facility.

4.5 Thermal and /or vacuum tests weekly planned for all flights hardware.

4.6. Another development desirable to finish - for a time been in a queue for a launch of nano-satellite, some advances appeared in hardware of energy harvesting. Incorporation of old Peltier’s elements into a thermal control subsystem of a nano-satellite can have visible benefits. Six Peltier’s elements on each sites of a cube can create simple passive thermal control with transfer of a heat from one side to another with skipping transfer of a heat of area inside Cubesat. Additional micro-controller with 1 nano-watt can allow not only to actively control temperature inside HD camera box on nano-satellite but also to harvest initial energy for powering power plant micro-controller. Such approach can benefit main mission's imaging subsystem thermal control.

4.7 Development for synchronization of the data in flash memory of a communication subsystem. That will reduce complexity of a video and pictures transferred by communication subsystem.

4.8 Needs to finish development of mobility subsystem software. That includes "on surface" movements algorithms (a) orientation of a ground station (as a version of the rover) to desired direction set by any individual micro-controller of on-board electronics or by mission control; (b) random path generation for obstacle avoidance; (c) generation by on-board micro-controllers sets of a the commands to perform matching of the orientation directions for a frame to perform forward-backward-turn movements; (d) set of commands to perform matching orientation direction for shaking movements for solar sensor and low resolution camera box dust's clogging; (e) set of commands to perform orientation position of a frame and antenna mount; (f) set of commands to perform orientation directions for low resolution camera stand and a frame of the rover to make a still picture; (f) processing the data from a solar sensor and on-board calculation of the direction of the sun.

4.9 Manufacturing gears for 1:5 and 1:12 ratio for use in ground station and on flight ready rover

4.10 Certification outgassing tests for a rover and impact shields.

4.11 Drop tests to confirm survivability of the rover on landing impact.

5.0 Critical risks to retire through development and verification activities

In “Mobility Subsystem, Task Risk Assessment” was mentioned risk for imaging subsystem, let see how this risk can be retire with planned tests. (Sorry - each planning of risk’s retirement in my head has association with soviet’s retired planning economy – my apologies in advance for clichés which deeply buried in a head from widely broadcasted annual communists party meetings)

5.1 Risk with stepper motor permanent magnets – will be confirmed by 3.1.b). After conformation another stepper motor can be chosen.

5.2 Risk with gear –it can be broken in mobility / imaging subsystem functionality - left this risk as it is. Probably another solution will be to made all parts from titanium. It can be 1 man day design, with delivery titanium part ready to be assembled with rover.

5.3 Risk that gyro-sensor can be failed because of out of operation temperature conditions or to be damaged by radiation. Design mentioned in 5.2 will be applied. Functionality of a rover with broken sensors can be verified by 3.4.2 test. Software solution to work without sensor will be considered.

5.4. Risk that accelerometer can be failed because of the same reasons as gyro-sensor. The same solution as mentioned above in 5.4.

5.5 Risk that power plant will fail to accumulate enough energy, Daily tasks mentioned in 3.1.a) can reduce a risk but it is impossible to eliminate it.

5.6 Risk that in time of the mobility of a rover low resolution camera stand can be broken. Combination of 3.1.b), 3.2.b), 3.2.c) will be applied. Test 3.4.2. can verified mobility and functionality of imaging subsystem in such event.

5.7. Risk that during movements pin holes in low resolution camera's box can be jammed with a dust, can retired by 3.1.a) and special algorithms to "shake" dust. To estimate risk, and verify solution it will be test 3.8.

5.9. Risk for hardware used in processing low resolution pictures, low resolution sensor, micro-controllers can be damaged by high energy particle. Design mentioned in 5.2 will be applied. To reduce risk possible to reduce amount of micro-controllers used for images' processing, solution mentioned in 5.1 can be applied.

6.10. Risk for FLASH memory to be damaged by high energy particles. Risk can be lowered by applying triple reserve of storage, process of lowering risk is 3.1.a), Tests 3.4.2 can be used for verification of survivability after introduced damage.

5.11. Risk - active and passive thermal control for a rover (HD and low resolution cameras) can fail. Retirement of this risk is a dream, but the test described in 3.7. can be used for verification. Solution described in 5.7 can be used to reduce risk.

5.13 Risk of failure in software algorithms to keep stable temperature condition. Way to reduce risk described in 3.1.a)

5.14. Risk of failure, partial or total, of a micro SD FLASH storage because of external radiation events. Risk was lowered by 3.4, and 4.4, cannot totally eliminated.

5.15 Risk of algorithms bugs/errors (in implementation of data exchange between units, or between units allocated remotely from each other), can be lowered by 3.1.a), cannot be eliminated.

5.15 Risk of algorithms bugs/errors (in implementation of data exchange between units, or between units allocated remotely from each other), can be lowered by 3.1.a), cannot be eliminated.

5.16 There is a risk that random path movements to avoid obstacles and "left" avoidance path both can fail to find a proper path. Way to reduce this risk is to use imagining subsystem to find heuristic solution in each individual case.

Appendix A. List all partner organizations expected to make substantial technical contributions to the team's development and verification activities in the Accomplishment Round.

atasonic Technologies Inc 2075 Brigantine Drive, Suite 2, Coquitlam, BC, V3K 7B8, Canada

Adobri Soltions Ltd. #1407 – 950 Cambie st. Vancouver BC, V6B 5X5, Canada

Appendix B. Team vision of a launch contract

In user guides of "Falcon 9", "Dnepr", "Rokot" launch vehicle is stated that minimum time from signing launch contract till moment of the launch is 18 months, all guides are strait forward in the matter of schedule.

In "Space Launch System. Dnepr. User's Guide". On page 76, in figure 18-1 it is described Launch Campaign Schedule with quarterly time line. Big chunk of time planned to be spend is for "Interface Control Document", "Release of documentation for additional hardware", and "Fabrication of necessary hardware", with total of 1 year. That means if launch provider partner SDB-YUZNOE in Ukraine will be willing (as it described in page 49) to provide for benefits of both sides already designed payload adapters/ locks, than 1 year can be reduced to a "Fabrication of necessary hardware" time frame. This is conformed on a page 71 about "LSA(Launch Service Agreement) for launch of a small spacecraft may be concluded 10 months prior to the planned launch date". In this case in "Design and Technical Documentation to be submitted by spacecraft authority" on a page 73 pp.3 "Detailed drawing of the spacecraft adapter interface with LV" will be predefined. "Project feasibility study" is another time reserve which can be used for beneficiary of both launch provider and its customer. On page 7-6 of another document "Rokot User guide" it is specified "Risk management" on second paragraph of 7.2.1.9 it is mentioned "Political Risk" with mentioning a partner company "Astrium" (51% EUROCKOT) providing financial backing all require funding. List of partners in Kosmotras (from Dnepr User's Guide) is impressive too, counting 15 members. All this opens the possibility to reduce time frame for launch vehicle integration. Falcon9 user's guide officially is less flexible on schedule, and our heritage not allows to fully estimate that process. From one point, quote obtained in 2011 about 1kg CubeSat showed that "time acceleration" is follow the same rules, in proportion 1-3. From another point, requirements for technical writing includes 19 books for a Rokot, 29 technical documents for a Dnepr, and 7 documents for Falcon9, which can makes Falcon9 more flexible for a selected customers.

Prices for Launch Service Agreement did not showed any significant changes in past 4 years. Established long queue of demands drive prices only high, and restriction on entry to a club, do not help market to conclude fair prices. Best described by a Space Shuttle paradox, prices depend on infrastructure around launch “event” itself. 1:10 ration between fair and “regulated” prices probably will not change in foreseen future.

To summarize, or basically to have a Launch Service Agreement needs to be "useful" for a launch provider somehow, ether by future possible business, or by amount of money. "Competition" frame, with its non-repetitiveness, is not the best attractive characteristic for launch provider, which makes launch "manifest" the "money first" choice. By following "the spirit" of Google XPRIZE useful be idea for discussion: "to lift-off all space equipment production from the earth to the Lunar surface", that (we still believe) can attract attention of today owners of a launch vehicles. It will be logical extension of today space industry status quo, and it is a matter of a time when it will be implemented, just next day after the competition, or in next loop of space rush.

That is our team’s vision of a launch contract - it is possible to touch the moon before end 2015.

Appendix C. Time required for systems development

manufacturing part	estimation	man-days
rover:		
wheels	2*16 *3d + 2d	98
frame's stepper motors holders	2 *4d + 2*2d	8
Connectors tubes	4 *2d	8

camera's stand	2d + 2d + 5d +2d	11
antenna stand	2d + 2d + 5d	9
Low res camera box(leg)	2* (3d +2d)	10
HD camera box	2* (3d +2d)	10
containers for temp stabilization	2d	2
container for capacitors	5d	5
helical antenna	4d	4
gears for cameras/antenna	2 * (2d + 2d + 3d)	14
power plant	5d	5
assembly	3d	3
Electronics 4 boards	4*5d	20
Nano-satellite		
frame	5d	5
stepper motors harness	5d	5
electronics 4 boards	4*5d	20
capacitor’s harness	5d	5
switch	2d	2
antenna deployment mechanics	5d	5
backup communication	5d	5
power plant	5d	5
ground station assembly	3d	3
craft		
impact shield	10*2d	20
craft frames	7*3d	21
mockup engines	6*3d	18
mockup payload adapter	4d	4
Tests, demonstration tests	14*2d	28
total +10%		385

For 385 man days, with 4 people working it is 6 month. In August 2014 it is possible to start procedures to incorporate craft into a payload compartment of a launch vehicle.

Incorporation will include manufacturing payload adapter. Max time frame for this operation On Jetasonic facility 1 month.

Appendix D. Key review and schedules.

Planned to conduct review of tests results sharp after each test done. Schedule published in Appendix E. Anybody from judges and public can attend, 3 days before test schedule can be adjusted. Most important reviews are

test N and summary	planned date & location	Objectives
3.4.1 Communication range test (25km) Rehearsal demonstration.	14 may 2014. Vancouver/ Burnaby/ Langley. BC, Canada.	To see full system is functioning from mission control to rover/nano-satellite.
3.5. Communication range test (min 100km) demonstration	2 July 2014 BC, Canada.	To see full system is functioning on distances comparable to LEO.
3.6.1. Vacuum (<1Torr) chamber test/demonstration (with nano-satellite inside)	2 August, 2014 Vancouver/ Burnaby. BC, Canada.	To check full system functionality in vacuum conditions.
3.7. Test of a thermal subsystem of a nino-satellite	17 August, 2014 Vancouver. BC, Canada.	To test performance of a thermal control subsystem.
3.8. Test with fully equipped rover with impact shield will be dropped from 70 m	1 September, 2014 BC, Canada.	To check LS and full system on landing impact.
3.9. Certification outgassing vacuum test of nano-satellite.	Launch date -1 month Ontario, Ontario,	To obtain certification for a flight on launch provider vehicle.
3.12. Flight-to-ground test.	Launch date + 1week.LEO +Vancouver/ Burnaby/ Langley. BC, Canada.	To get experience in controlling craft on orbit, determination of the orbit, full system functionality in real space flight.
3.11. Vibration and acoustic study of a craft's mock-up.	1 October 2014 Vancouver/ Burnaby/ Langly. BC, Canada.	To attract attention of a public [to a scpoe of testing procedures in space industry.]

Appendix E. Summary of each of the tests, including the following information:

test N and summary	planned date	Location	item to be tested	Objectives
3.4.1 Communication range test (25km) Rehearsal demonstration.	14 may 2014.	Vancouver/ Burnaby/ Langly. BC, Canada.	full system	to check full functionality of a nano-satellite and rover(as a ground station)
3.4.2 Rehearsal up-side-down demonstration test	26 may 2014	2014 Vancouver/ Burnaby/ Langley. BC, Canada.	full system/broken system	to check full functionality of a nano-satellite and rover(as a ground station) in SNAFU situations.
3.5. Communication range test (min 100km) demonstration	2 July 2014	BC, Canada. (probably WA)	full system	to check full functionality of a nano-satellite and rover(as a ground station), with RF communication on distances comparable with LEO
3.6.1. Vacuum (<1Torr) chamber test/demonstration (with nano-satellite inside)	2 August, 2014	Vancouver/ Burnaby. BC, Canada.	full system	to check full functionality of a nano-satellite and rover(as a ground station)
3.6.2. Vacuum (<1Torr) chamber test with rover (ground station)	15 August, 2014	Vancouver/ Burnaby/ Langley. BC, Canada.	full system	to check full functionality of a nano-satellite and rover(as a ground station)
3.7. Test of a thermal subsystem of a nino-satellite	17 August, 2014	Vancouver. BC, Canada.	thermal subsystem	to check to check full functionality of a nano-satellite and rover(as a ground

				station), to check thermal subsystem
3.8. Test with fully equipped rover with impact shield will be dropped from 70 m	1 September, 2014	BC, Canada.	full system	to check full functionality of a nano-satellite and rover(as a ground station)
3.9. Certification outgassing vacuum test of nano-satellite.	Launch date -1 month	Ontario, Ontario, Canada	nano-satellite	To certify nano-satellite
3.10. Vibration and acoustic test, for certification of the nano-satellite to flight	Launch date -2 weeks	Vancouver/ Burnaby/ Langley. BC, Canada.	nano-satellite.	full system to certify nano-satellite for flight
3.11. Vibration and acoustic study of a craft's mock-up.	1 October 2014	Vancouver/ Burnaby/ Langly. BC, Canada.	full system	to check full functionality of a craft and rover (in assembly)
3.12. Flight-to-ground test.	Launch date + 1week	LEO +Vancouver/ Burnaby/ Langley. BC, Canada.	full system	to check full functionality of a nano-satellite and rover(as a ground station)
3.13. Certification outgassing vacuum tests for a rover and impact shield.	Launch date of nan0-satellite + 2 month	Ontario. Canada	Mobility system+ landing system	to certify parts of a craft for a space flight
3.14. Certification vibration tests for fully assembled craft.	Launch date of nano-satellite + 6 month	At launch provider facility.	full system	to certify craft for lunar flight

Appendix G Verification Matrix for the subsystem

technical requirements	31a	31b	31c	32a	32b	32c	32d	33a	33b	33c	33d	341	342	35	361	362	37	38	39	310	311	312	313	314	315	316	317	318	319	320
operation temperature for all mechanism used in		x															x	x	x			x	x							

imagining system -70 + 125C.																														
Dust conditions for mechanisms - particles size 10% < 5mkm < 10% < 20mkm < 10%, < 50mkm < 30% < 0.5mm < 40%													x									x								x
Temperature operation conditions for electronics used in imagining sTemperature operation conditions for low resolution imagining sensors -20+85C.		x															x	x	x			x	x							
Temperature operation conditions for HD camera -20+85C./> Temperature operation conditions for HD camera -20+85C.		x															x	x	x			x	x							
Performance by mechanisms - stand for box with low resolution camera has dual use - as a sent to lift camera for high observation point, and as a leg for movements of all rover.													x						x			x								
Resonance frequency for mechanics must be not equal of a frequencies of another part of the rover and craft's frame, or crafts engines. Low resonance frequency of a mechanism of a imagining subsystem must be high than 30 Hz.					x																									
High resolution camera needs to delivery 5megapixel picture and HD video 720p												x										x								
technical requirements	31a	31b	31c	32a	32b	32c	32d	33a	33b	33c	33d	341	342	35	361	362	37	38	39	310	311	312	313	314	315	316	317	318		
common storage FLASH memory 1Gb																						x								
in a range of -20C+85C inside box with low resolution cameras		x															x	x	x			x	x							
in a range -20C +85C inside		x															x	x	x			x	x							

HD camera's box																														
Interface with communication subsystem needs to be capable to delivery (via ground station) to mission control pictures and video in noisy environment around a ground station. Delivery of a video from micro SD FLASH storage needs to be traced as low as possible to broken/lost packets. Restoration of broken data can be done days after communication session.											x	x	x	x	x		x				x									
Orientation precision 0.1 degree for a craft, and 0.1 for a nano-satellite																					x						x			
On LEO it is 100 m in position, and 1 m /s in velocity.																					x									
On trans lunar trajectory 100m in position and 1 m/s in velocity.																														
Laser range measurements on descend 10 m in position, with 10 measurements per second.																								x						
Communication subsystem - TX power in peak 10Wt, sensitivity -145 dBm.																					x									
GPS raw data orbit determination with precision of 100m in position and 1 m/s in velocity.																					x									
At least 1% accuracy for impulses of all engines except brake engine. At least 1% accuracy in profile of the performed trust of the brake engine.																										x				
To support soft touchdown of the rover with max acceleration of 362g and expected acceleration of																	x													

40g.																														
technical requirements	31a	31b	31c	32a	32b	32c	32d	33a	33b	33c	33d	341	342	35	361	362	37	38	39	310	311	312	313	314	315	316	317	318		
To reduce rotation of a impact shield and rover from 5/sec to 1 per min after separation from burned brake engine.																		x												
To orient rover and impact shield by impact shield side before impact with lunar surface.																		x												
To support thermal operational conditions automatically.															x	x	x													
To support communication session orientations automatically.																						x								
Torque holding stepper motors 0.36Nm and 0.21Nm																													x	
Gear for low resolution camera and antenna stand 1:3 minimum																													x	
Gear for earth mobility simulation 1:8 and backup gear for lunar surface 1:4																													x	

full stop. And now we can talk. About – How to reach the moon without attracting attention of medical personal.