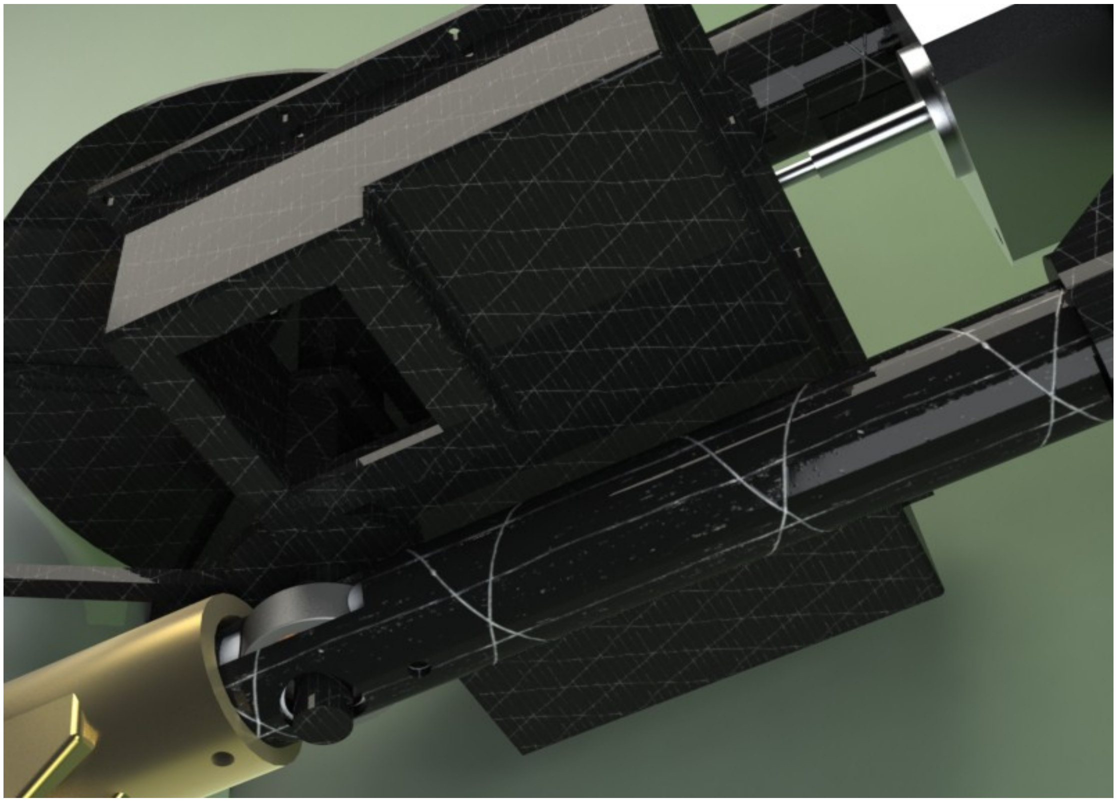
Team PlanB, Imaging Subsystem, Development and Verification Plan



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Acknowledgments

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1.0 Summary

You can find detailed description for imagining subsystem in "Imagining subsystem Technical Risk Assessment" document. Let's mention some highlights of that subsystem.

The imaging subsystem is a combination of hardware and software that provide work of low resolutions, and HD cameras. Software supports storage for HD video and pictures, storage has triple reserve. Mechanical part includes stand housing on its top the box for 4 low resolution cameras. Instead of optic used 4 pinholes to take images simultaneously by imagining sensor of 4 cameras. Stand is a carbon fiber rode. Rotation mechanism of a stand powered by stepper motor and via open gear can lift camera's box up to 0.5m from lunar surface. Observation from highest point necessary before choosing direction of rover's movement. HD resolution camera located low from the ground in a sealed carbon fiber box. Special sealing applied to protect box from pressure leakage. There is triplex glass window to have optical view from inside a box. HD camera box mounted on an antenna rotation mechanism of the rover. Movements of an antenna mount allow digging 1-2 cm into a lunar surface.

Low resolution cameras can take JPEG pictures and stored image (sizes RGB 640x480) inside internal memory. Retrieving images and video can be done by commands transferred from mission control. Storage is FLASH with tipple reservation with writing simultaneous to 3 devices and by read done with is majority voting 2-from-3.

Thermal control includes a combination of passive and active methods. For active thermal control HD camera used 2 temperature sensors. Micro-controller checks the temperature values and makes decisions what to do in "on orbit", or in "on moon" modes. On temperature functions calculated derivatives of a temperature. Decision for active thermal regulations made based on derivatives (updated regularly) or based on direct measurements of heat flow.

Cameras can be switched on / off at temperature’s operation conditions.

HD Camera is picked from shelf of Best Buy shop and was tested for temperature conditions +125C -75C, without Li-Ion battery and without micro SD memory, to be selected camera passed three 1.7m drop test on concrete floor (30g).

Electronics was designed / manufactured to support low/high resolution cameras.

Interface of subsystem includes connection to inter-unit serial communication loop, then to a RF communication subsystem, then to Ground station and last to mission control. Mission control designed to be dynamic, capable to rapid modification, tool for main and test mission control. Software based on concept of a "state machine" with serial communication between micro-controllers type units.

2**.0 Imaging subsystem's current stage of development. Explanation of any critical technical risks or challenges that the team has already overcome.**

2.1 Mechanisms of imagining subsystem.

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.

2.2 Cameras & image processing capability.

Challenge for camera functionality and ability to take picture and 720p video was not considered as a challenge, but rather home exercise. Challenge to adapt camera for vacuum operational conditions was overcome, 0.2mm hole made in protection glass to allow camera to work in vacuum conditions. Challenge to choose optic for low resolution camera was overcome - all 4 low resolution cameras will use "camera obscura optics" (pin hole) as optical element. Challenge for compression / decompression of the jpeg images from row RGB data was overcome, source code for such compression was ported to two type of processor - Intel and Z-80, and ready to port to other type of micro-controllers.

HD camera selection process includes drop and temperature tests before selection.

Challenge to keep HD camera under desired temperature operation conditions was overcome by sealing camera into pressurized box. Two type epoxy with low outgassing parameter was chosen for such sealing operation. A special temperature stabilizer container was considered to use as additional inserts into a HD camera box. Challenge for creation harness for HD camera was successfully overcome, harness embedded into box in a time of box's manufacturing, and holds HD camera still. Challenge for tight sealing of the box overcome by adding less than 0.05% of a graphene into a epoxy used in HD camera box. Challenge of protection of a HD camera from expose high temperature in curing process was overcome by choosing air-dry low outgassing epoxy. Additional sealing technique uses (a)indium metal sealant and (b) bolts to tide box's cover. Challenge for observation window manufacturing was overcome by choosing triplex glass picked up on car's junk yard.

2.3 Challenges in camera's thermal control.

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.

Challenge active thermal control in "on orbit" mode of operation was solved by embedding calculations and storing derivatives of a temperature's measurements, done in different orientation position of the craft. For such software implementations was considered testing scenarios with heat source and cooling applied to prototype of a nano-satellite.

[Challenge in passive thermal control for a test mission will be resolved by applying 6 Peltier elements to each side of nano-sattelite. Connecting pairs from opposite sides allow to transfer heat from heated to a heat radiated site.]

2.4 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.

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

4.1 As alternative for already chosen low resolution cameras can be selected different image sensor. In that case it will be software development to accommodate interface for the sensor, and porting of existing code for jpeg compression into micro-controller architecture. That can simplify hardware for low resolution camera box. One of benefit - imagining subsystem in this case can provide information for attitude control / orientation subsystem of the craft. Together with process of taking picture can be calculated direction the center of celestial body appeared on a picture. Another benefit is a control of a quality of the picture. Despite huge amount of patents on video/image compression, modern compression depends on 200 year's old Fourier transformation. That mathematics allow for "nature" (with source from nature) function, (and pictures is one of such function) to skip small details of the image by skipping high frequency spectrum of transformed function. Controlling level of "skipping" dynamically, by accounting the performance of a communication and power plant subsystems can give advantage in mobility and functionality of a rover. It is a preferable development, but it depended on other tasks in development. Delay in test mission can make such development happened, and "on time" launch on nano-satellite in spring of 2014 can postpone this.

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

4.3. Assembly of nano-satellite together for imaging subsystem low resolution / HD camera has to be done.

4.4. 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.

4.5. 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.

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

4.7. 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.

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

5.0 Critical risks to retire through development and verification activities

In "Imaging subsystem, Technical Risk Assessment" was mentioned risk for imaging subsystem, let see how this risk can be retire with planned tests.

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 "Imaging subsystem, Technical Risk Assessment" 6.2 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 described in [] 1.1. To estimate risk, and verify solution it will be test 3.8.

5.8. Risks for low resolution cameras sensor to be out of operational temperature conditions. Risk can be verified 3.1.b). Solution mentioned 4.1 can be applied.

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 [] 6.2 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.

5.10. 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 both HD and low resolution camera can fail. Retirement of this risk is a dream, but the test described in 3.7. can be used for verification. Solution described in 4.7 can be used to reduce risk.

5.12. Risk - camera's li-ion battery can be damaged by out of operation temperature conditions. Risk cannot be eliminated, only reduced. Test described in 3.7 can assessed functionality with damaged battery and power provided by power plant.

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.

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

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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 landing subsystem 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 Mooncast Ground Demonstration.

Mooncast Ground Demonstration will be provided on 3.4.2 Rehearsal up-side-down demonstration test. 26 may 2014 Vancouver/ Burnaby/ Langley. BC, Canada. Description for the test is in 3.4.1 and 3.4.2

Appendix F. 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	1 September, 2014	BC, Canada.	full system	to check full functionality of a nano-satellite and

will be dropped from 70 m				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
operation temperature for all mechanism used in imagining system -70 + 125C.		x															x	x	x			x	x					
Dust conditions for mechanisms - particles size 10% < 5mkm < 10% < 20mkm < 10%, < 50mkm < 30% < 0.5mm < 40%													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 HD camera's box		x															x	x	x			x	x					
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						

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