Questions and Answers

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1. Introduction

This document provides answers to questions related to the rules, guidelines, and the competitive process for the DARPA Subterranean (SubT) Challenge. Most of the questions have been collected from posts in the SubT Community Forum (https://community.subtchallenge.com). Competitors are encouraged to post questions to the SubT Community Forum to encourage discussion with other competitors and the DARPA Team.

Discussions and answers posted by the DARPA Team on the SubT Community Forum are considered provisional. DARPA intends to provide timely and accurate information in the forums; however, all comments, responses, implications, etc. are superseded by officially released *SubT Question and Answer* documents found under the "Resources" section of the official SubT Challenge website (www.subtchallenge.com/resources.html). Questions may be edited for clarity, punctuation and grammar.

This document is subject to change and may be superseded by later versions. The latest official versions of all documents will be posted to the SubT Challenge Website and the SubT Community Forum.

2. Overview

The DARPA Subterranean Challenge is organized into a Systems Competition and a Virtual Competition. Teams in the Systems Competition are developing physical systems to compete in live events on physical, representative subterranean courses. Teams in the Virtual competition are developing software and algorithms using virtual models of systems, environments, and terrain to compete in simulation-based events. The Systems Competition includes Track A (DARPA-funded teams) and Track B (Self-funded teams). The Virtual Competition includes Track C (DARPA-funded teams) and Track D (Self-funded teams). For more information regarding the tracks in the Systems and Virtual competitions, please see the *SubT Challenge Guidelines*.

3. Questions Answered as of October 31, 2018

1. **Question:** Is the registration for this challenge still open?
   Answer: Yes, Team Registration will remain open on a rolling basis but teams are encouraged to register early to avoid missing important updates and deadlines. Please see the *SubT Challenge Guidelines* document for additional information on qualification and event registration requirements.

2. **Question:** What are the eligibility requirements for a team?
   Answer: Please see the Terms and Conditions on the Team Registration Page which can be found on the SubT Challenge website. Teams of all kinds are welcome and encouraged to

participate including but not limited to small/large companies, universities, startups, individuals, US-based, and international participants.

3. **Question:** Are interactions between the four different tracks allowed and/or encouraged?
   Answer: Yes, interactions between all four competition tracks are allowed and strongly encouraged with the goals of fostering a vibrant research community, encouraging technical exchange between competition tracks, and accelerating development of leap-ahead capabilities.

4. **Question:** Will Virtual Track teams be able to later transition to Systems Track teams if their capabilities are promising enough to warrant it?
   Answer: Any team is eligible to participate in the Self-funded Systems Track (Track B) regardless of their participation or performance in the Virtual Competition. DARPA does not plan to provide or award Government Furnished Equipment (GFE) hardware to any Virtual Track teams.

5. **Question:** Will there be down-selection or combination of teams between program milestones? What metrics or performance criteria will be used to determine which teams move on to successive phases?
   Answer:
   - High-performing Track B teams are eligible to become a DARPA-funded Track A team during the Finals Stage. DARPA intends to fund up to six teams ($1.5M each) in the Finals Stage out of the teams competing in Track A and Track B. The determination will be based on participation and performance in the Systems Circuit Events.
   - High-performing Track D teams are also eligible to become a DARPA-funded Track C team during the Finals Stage. DARPA intends to fund up to six teams ($250K each) in the Finals Stage out of the teams competing in Track C and Track D. The determination will be based on participation and performance in the Virtual Circuit Events.

6. **Question:** Has there been thought of providing a partially known environment (for example the tunnel map before an earthquake) or will it always be completely unknown?
   Answer: The spirit and intent of the competition is to develop technologies capable of exploring and operating in unknown environments. The degree to which the environment is partially known may depend, in part, on site availability and could vary across events.

7. **Question:** Is there some progression between the three circuits?
   Answer: Each of the three Circuit Events will focus on a specific subdomain in the following order: Tunnel Circuit, Urban Circuit, and Cave Circuit. The order of Circuit Events is not intended to imply that any one subdomain is easier or more difficult than any other. Each subdomain presents its own unique technical challenges, but each Circuit Event is expected to stress all four technical areas of autonomy, perception, networking, and mobility.

8. **Question:** Are you allowed to retrieve the robots after the challenge?

Answer: No manual physical intervention or entry by any (human) team members on the course will be permitted. Only trained and authorized DARPA personnel will be allowed to enter the course preceding, during, and following the test run. Any systems that have not autonomously exited the course at the termination of a run will be retrieved by authorized DARPA Competition Staff.

9. **Question:** When will additional details be released about the specific locations of the planned events?
   Answer: Additional details about event locations and logistics details are expected to be announced no later than 3 months before each event.

10. **Question:** When will additional details be released about the specific course features, artifacts (a.k.a., objects of interest), and environmental conditions?
    Answer: The *SubT Challenge Guidelines* document represents the level of detail that is expected to be released at this time. Additional details will be released to competitors alongside the draft *SubT Challenge Rules* document expected to be released no later than 9 months before the Tunnel Circuit. Additional event-specific details will be released alongside the finalized rules for each event, expected no later than 3 months before each event. DARPA is interested in versatile and resilient systems. Any course features or environmental conditions commonly found in representative subterranean environments are fair game unless specifically determined to be out of scope. Extreme temperatures, fire, and hazardous materials are not expected to be within scope.

11. **Question:** How will communication bandwidth between robots be limited, and will we have the chance to test in this communication environment before fall 2019?
    Answer: It is expected that the course environments will impose significant impediments to reliable networking and communications links. DARPA is not currently planning to artificially limit communication links. The SubT Integration Exercises will provide teams with an opportunity to test their systems on representative testing environments. Teams are encouraged to identify additional testing environments to support their development efforts.

12. **Question:** What level of source code and/or higher level routines will be provided for the virtual platform models? For example, will obstacle avoidance be included?
    Answer: Source code will be available on the SubT Tech Repo. Individual joint actuation will not be required - other than in the case of special exceptions, most platforms will be controllable through velocity-based ROS Twist messages. Subroutines including path planning and obstacle avoidance will not be explicitly provided, though teams are encouraged to utilize open-source resources.

13. **Question:** Will artifact detection source code be available in the repo, or are virtual track teams expected to develop their own? Are systems track teams providing their algorithms for virtual track teams?

Answer: DARPA does not anticipate providing artifact detection source code. DARPA is not requiring DARPA-funded Systems Track teams to provide their algorithms for Virtual Teams unless they choose to do so. All teams are encouraged to leverage open-source resources. See also Question #12.

14. **Question:** Will DARPA provide a training set of image data for detecting artifacts (a.k.a. objects of interest)?
    Answer: DARPA does not plan to provide a training set of image data. Teams may choose to use various sensor modalities including but not limited to: visual, LIDAR, thermal, acoustic, RF, and multi-gas sensors. DARPA plans to announce the artifacts for each circuit as part of the finalized event rules (no later than 90 days before each event).

15. **Question:** Will artifacts (a.k.a. objects of interest) be adequately illuminated?
    Answer: The courses are expected to include conditions ranging from lighted areas to complete darkness. It is not guaranteed that the artifacts will be illuminated.

16. **Question:** Is the capability to open doors a requirement of the challenge?
    Answer: Teams are not required to have the capability to open doors.

17. **Question:** Is there opportunity for sponsorship and would DARPA help with that?
    Answer: Sponsorship from either your own organization or outside organizations is allowed. DARPA does not anticipate directly supporting such efforts.

18. **Question:** Is any operator interaction expected or will the mission start at the entrance of the cave?
    Answer: DARPA is not explicitly ruling out limited operator input, but it is expected that high levels of autonomy will be necessary for success in the competition. DARPA is expecting to only allow one human operator and the environment itself will impose significant challenges to teleoperated approaches.

19. **Question:** Is a physical link between robots and the base station permitted?
    Answer: DARPA does not anticipate prohibiting physical links. However, teams should seriously consider the limitations imposed by large-scale, potentially dynamic, complex environments.

20. **Question:** Is teleoperation of systems permitted? Are there any constraints on this besides comms limitations?
    Answer: Please see Question #18 and Question #19.

21. **Question:** How often do you expect to update questions on the forum and provide "official" answers?
    Answer: DARPA is currently working on responding to the many questions that were received leading up to, during, and after Competitors Day. It is expected that many answers will be

posted within the next few days. The goal is to respond to questions as quickly as possible, but the response timeline will depend on the question. Some questions may be referred to a future information release (e.g., draft *SubT Challenge Rules* document).

22. **Question:** Is there a minimum resolution required for the 3D maps sent to the command post?
Answer: DARPA has not specified a minimum resolution for the 3D maps. However, stakeholders and spectators will likely form opinions about the quality of a team's solution based on their map representation.

23. **Question:** It is asked to provide map updates at 1 second. From an autonomy perspective it can be that a valid solution sends a subset of the robot team outside of communication range to other robots and the human commander. Then this would mean that the part of the map they explored is sent to the DARPA command post all at once. Is this valid and allowed? Of course scoring of artifacts detected during this part of the map will be based on the time the report was received. The question is if this is valid with respect to the map update requirements.
Answer: Teams may determine the best approach for their mapping strategy and updates. Depending on communication and mapping strategy, it may be valid for a team's map updates to not contain significant new information for a period of time.

24. **Question:** How similar will the SubT Tech Repo environment models be to the Systems Competition Test Courses? If they are the same or similar, when will they be released?
Answer: DARPA intends to release additional virtual environments on a rolling basis. It is expected that these releases will eventually include models of the Systems Competition Test Courses. However, DARPA does not currently plan to release any virtual models of the Systems Competition Test Courses until after the respective Circuit Event has been completed.

25. **Question:** For Track A teams, what level of detail is required for sensing modalities not present in the current SubT Virtual Testbed? (e.g., thermal, radar)
Answer: DARPA will work with Track A teams on an individual basis to determine a reasonable level of fidelity for any sensing modalities not currently available.

26. **Question:** How will the parameters of the systems and virtual track competitions differ? For example: mission duration, number of agents, artifacts, challenges, etc.
Answer: It is expected that most of the parameters between the Systems and Virtual Competitions will be very similar. More details will be released in the finalized *SubT Challenge Rules* documents expected to be released no later than 3 months before each competition event.

27. **Question:** What is defined as manual intervention? Is relaying information to the mapping robot considered as intervention?

Answer: A human supervisor is allowed to communicate with the deployed systems. No manual physical intervention or entry by any (human) team members on the course will be permitted. See the *SubT Challenge Guidelines* document (Rev. 1, Section 8.5.2) for more information on what manual operations are allowed in the Staging Area.

28. **Question:** Are human operators allowed to help with the identification of artifacts via manual monitoring of camera or other sensory feeds? Ex. Robot sends back potential artifact location and human operator verifies accuracy before passing data along to the DARPA command post.
Answer: Teams are permitted to monitor and manage the communications with their deployed systems/solutions as they choose. For Systems Teams, this may include inputs from a human supervisor. The specific interface for providing artifact reports to the DARPA Command Post will be provided at a later time.

29. **Question:** Can artifacts be tagged via human identification (e.g., image snapshot inspection)?
Answer: Please see Question #28.

30. **Question:** Is the operator ultimately responsible for reporting the detections? What will the interface to report detections be like? Is the operator able to filter detections? Can the operator choose to drop an incorrect detection? Can the operator "create" a detection based on human understanding after receiving visual feedback + xyz data from the robots?
Answer: Please see question #28.

31. **Question:** Could we be provided with a bounding box relative to the starting point that delimits the range of the course? This could help to inform exploration strategies. Similarly, are we allowed to put up a QR-like code at the beginning of the course to mark the base?
Answer: DARPA does not intend to provide a bounding box for the course. It is anticipated that temporary aids are likely to be permitted within the Staging Area.

32. **Question:** Are there penalties for false-positive detections of artifacts?
Answer: To mitigate the potential of arbitrary guesses and penalize excessive false-positive detections, DARPA may limit the total number of scored reports (e.g., twice the number of total artifacts).

33. **Question:** How do I obtain the SubT Virtual Testbed for local testing? As I understand it the initial version SubT Virtual Testbed may have been released already. I uploaded a new copy of ROS the other day, but did not see it among the models present (though perhaps I just missed it). Is it available to download/Update ROS with?
Answer: The SubT Virtual Testbed is not part of the official ROS release. It is a separate package that depends on ROS Melodic and Gazebo9. You can find the code at https://bitbucket.org/osrf/subt. There are also tutorials, including installation tutorials, at https://bitbucket.org/osrf/subt/wiki/tutorials.

34. Question: Exactly how much information is necessary about each artifact? Is only <x,y,z> and class reported to DARPA command? Or is DARPA also interested in seeing other sensor readings regarding classifications? What is the end deliverable for artifact classification?

Answer: Each artifact report must include the type of artifact and its georeferenced location. The location must be reported in the form of Cartesian coordinates (x,y,z) relative to a global origin (0,0,0) marked by a fiducial in the Staging Area. DARPA does not expect to require additional information in the artifact reports. Additional details of the interface to the DARPA Command Post will be provided in the draft *SubT Challenge Rules* document expected to be released no later than 9 months before the Tunnel Circuit.

35. Question: Are there power or band restrictions on communications? Specifically, do we need to stay under a certain power limit for radio communications, and are we restricted to specific bands? Do all communications need to be FCC-legal?

Answer: DARPA is interested in novel networking solutions and will work with teams to get their approaches approved if possible. However, each competition event location may have wireless spectrum limitations including potentially FCC guidelines. Teams are encouraged to raise any potential concerns about their planned approaches early. Additional site-specific details will be released in the draft *SubT Challenge Rules* document and/or the event *Operations Guide* documents.

36. Question: Does the artifact location or classification matter more? How will artifact scores be weighted?

Answer: Please see Section 9 of Rev. 1 of the *SubT Challenge Guidelines* document. Both the object type and location accuracy must be valid for the artifact report to be scored.

37. Question: Is there a finishing time penalty or reward?

Answer: Please see Section 9.2 in Rev. 1 of the *SubT Challenge Guidelines* document for a description of the time-based scoring of artifact reports. There is no additional penalty or reward for a team completing a run before their time expires.

38. Question: Will DARPA personnel be in the environment while the system is running? Should we expect all "dynamic objects" to be environmental hazards, rather than people / other robot teams? Will dynamic obstacles include live human beings?

Answer: It is possible that DARPA personnel will be in the environment during the runs, but any personnel are not expected to be visible to deployed systems. DARPA does not anticipate using personnel as dynamic obstacles. Only one team at a time will be operating on the challenge courses. However, DARPA may choose to utilize automated methods of implementing dynamic obstacles.

39. Question: Are there any high voltage cables running through the area (e.g., subway), or can we expect them to be turned off? Will high voltage lines interfering with communications be something we have to contend with?

Answer: DARPA does not expect to have exposed high-voltage subway rails in the challenge courses. It is possible that the environments will include powered electrical wires commonly found in household or industrial environments.

40. **Question:** For qualification - what are "baseline safety measures" and "baseline performance capabilities?" Will these change as we get further into the competition (i.e., a new metric before each circuit?)
Answer: Please see Section 6 in Rev. 1 of the *SubT Challenge Guidelines* document for information regarding qualifications. Additional details will be released in the SubT Challenge Qualification guide, were released on October 31, 2018. It is possible that the qualification requirements will be adjusted between events to account for site-specific considerations.

41. **Question:** Are all artifacts worth the same point value? Or will some high priority artifacts be awarded more points than others?
Answer: Please see Section 9.2 in Rev. 1 of the *SubT Challenge Guidelines* document for information regarding time-based scoring of artifact reports. Other than time-based scoring, it is expected that all artifacts will have the same value.

42. **Question:** Are we going to be evaluated by map quality?
Answer: Please see Section 9.3 in Rev. 1 of the *SubT Challenge Guidelines* document.

43. **Question:** Do the robots need to report out complete 3D maps to base? Or is accuracy of artifact location a sufficient proxy for this info?
Answer: Please see Section 9.3 in Rev. 1 of the *SubT Challenge Guidelines* document.

44. **Question:** What is the minimum size of opening the vehicle needs to be able to go through?
Answer: Please see Section 8.5.3 in Rev. 1 of the *SubT Challenge Guidelines* document.

45. **Question:** In reference to the "need for exclusive handling [of deployed robots] by competition staff," under what circumstances will competition staff not bring back deployed robots? Do the systems have to be carryable by one person, two people, or a team of people? Will DARPA staff power on the deployed platforms and teleoperate them back to base? Will they push/roll/move on a cart deployed robots? How long will DARPA staff spend picking up/looking for deployed platforms?
Answer: The systems are not required to be hand-carried. Safe handling instructions will be required as part of the team-provided Handling Manual described in Section 8.5.3 in Rev. 1 of the *SubT Challenge Guidelines* document. For larger systems it is possible that safe handling may include a powered remote-operated procedure or transportation by cart.

46. **Question:** How much comm loss time to the team is considered as "reasonable"? When does DARPA terminate the run due to comm loss? If the team remains operational (e.g., there is visual feedback from cameras in the circuit showing that it continues executing the mission)

but communication to the operator has been lost temporarily, what is the window DARPA will allow until it terminates the run?

Answer: DARPA does not anticipate terminating a run due solely to a loss in communication with the deployed systems. Please see Section 8.5.1 in Rev. 1 of the *SubT Challenge Guidelines* document for additional information for run termination conditions.

47. **Question:** Are there concepts for how to accurately define the location of the gas related artifacts? It seems as though we need to accurately delineate the source of gas leaks - will this location be visually distinctive?

    Answer: Additional details on localization of non-discrete artifacts will be provided in the draft *SubT Challenge Rules* document expected to be released no later than 9 months before the Tunnel Circuit.

48. **Question:** If more information becomes available, can the system provide an update to a previously reported object, possibly refining its location? How will the update be scored?

    Answer: Please see Section 9.2 in Rev. 1 of the *SubT Challenge Guidelines* document.

49. **Question:** (Follow up to Question #48) What happens if a team submits a duplicate artifact report for an already valid and scored report for the same artifact? Which time is used to evaluate the score? Do updates on known correctly identified artifacts count against the allowed total number of reports?

    Answer: Each artifact report will count against the allowed total number of reports regardless of validity. Regarding score values, additional details are expected to be released alongside a more detailed scoring function in the draft *SubT Challenge Rules* document expected to be released no later than nine months before the Tunnel Circuit.

50. **Question:** The draft rules document indicates that the goal will be to localize the artifacts with respect to a DARPA-defined frame of reference. There is mention made about a fiducial that defines the origin of the coordinate frame but it seems as though it will also be important to establish the orientation of the robots with respect to this frame. Small deviations in angle can easily translate to large errors over the scales of kilometers. Are there any concepts for how we can accurately establish our robots position and orientation with respect to the DARPA frame in the staging area?

    Answer: Additional details regarding the fiducials will be provided in the draft *SubT Challenge Rules* document expected to be released no later than 9 months before the Tunnel Circuit. It is likely that DARPA will provide sufficient numbers of fiducials to define, e.g., an origin and orientation.

51. **Question:** What are the specifics of the fiducial setup? How far out/in the ingress point to the environment? How many and how big? When is the earliest we can expect a sample setup?

    Answer: Please see Question #50.

52. Question: Will Virtual Teams be allowed to reconfigure platform and sensor models to compose custom configurations?
Answer: It is expected that each platform model type will have a defined set of allowable sensor configurations. The number of platforms and configurations available in the SubT Virtual Testbed is expected to grow significantly on a rolling basis over the duration of the competition. Teams may request or contribute models or configurations for inclusion in the SubT Tech Repo, but no guarantee is provided that such requests will be approved. Any new models will need to undergo review and validation before being included in the repository. Note that a model contributed by a team, if found viable and deemed appropriate for the spirit of the competition, will be made available to all teams through the SubT Tech Repo.

53. Question: Is it possible for artifacts to move during a single run? If artifacts move (we knock them over, they fall down, etc.), do the global reference locations get updated? Can we expect artifacts to change location/be dynamic?
Answer: DARPA does not anticipate moving artifacts within a single run. It is expected that the artifacts will be reasonably secured as to not fall or move within a single run.

54. Question: In the DARPA LAGR challenge one team's strategy for navigating was to use their first run in the environment to map it, and get points in subsequent runs leveraging the map from the first run. This challenge would seem to have us also doing multiple runs in the same tunnel system. If this is the case, it seems like leveraging knowledge from previous runs would be advantageous to the team. Even without 'hacking' and using the previous runs map, the 'operator' in the staging area will also likely gain knowledge of the course in subsequent runs. The spirit of the program seems to be going into novel/unknown environments with little prior knowledge, which is contrary to doing this. Is there a mechanism or 'hacking'. Is there a rule in place like "you will not use prior maps" or sufficient diversity in runs to prevent teams doing this?
Answer: The spirit and intent of the SubT Challenge is to develop technologies to rapidly and remotely explore complex and unknown environments. Teams that align their solutions to these goals will be significantly more likely to succeed in the competition. DARPA intends to take multiple approaches to limiting the viability of approaches that leverage prior knowledge from earlier runs (e.g., competition rules, schedule, course layout). See also Question #6.

55. Question: The System Track score will be the best of multiple runs. While you might change the course and locations of artifacts and barriers, there is probably a limit to how much the course might change. Knowledge gained on previous runs might prove useful (at least statistically) on future runs. Are we allowed to use that knowledge or do we need to purge that information from the bots minds before each run?
Answer: Please see Question #54.

56. Question: Is there a limit on number of robots to be used in the competition? Is it OK if a competitor uses only one robot (e.g., UAV) to complete the task?

Answer: DARPA is not requiring a minimum number of deployed systems; however, teams are encouraged to consider the large-scale environments of interest, complexity of the expected mobility challenges, and likelihood of attrition in unknown and possibly dynamic environments. See also Question #57.

57. **Question:** Is there any rule on number and type of robots which can be used in the competition?
    Answer: DARPA is interested in solutions that are cost-effective and attrition-tolerant. While there are currently no limits on the total quantity or aggregate cost of deployed systems, DARPA may introduce additional constraints as the competition progresses to appropriately incentivize such solutions. See also Question #56.

58. **Question:** Will the Virtual Track include AWS GPU resources free of cost? How do we access those resources for the virtual testbed?
    Answer: Cloud simulation will be released as part of the Version 3.0 Virtual Testbed Release (May 2019). DARPA expects to provide a set amount of AWS simulation time free of cost to teams that have completed qualification. These hours are intended to provide teams ample access to cloud resources to familiarize themselves with submitting their solutions to the SubT Virtual Portal. Though the SubT Virtual Testbed 3.0 will still be fully functional as a local instance, additional cloud resource time will also be available for purchase from AWS from that point onward. Unregistered or unqualified teams will not be allotted free cloud resource hours but will still have the option of purchasing cloud simulation time.

59. **Question:** How exactly does the comms broker plugin function? Does it drop packets in the roscore, and does it report out a packet is dropped? Is it based on line-of-sight of robots, a throughput limitation? Do we need to feed it pose or transform data?
    Answer: The communications feature of the SubT Virtual Testbed does not utilize a ROS interface. Its initial C++ implementation is reliant on distance-based interpretation of neighbors with limitations on both data size and rate – further details regarding specific operation are available at https://bitbucket.org/osrf/subt/wiki/api. DARPA expects to continuously improve the fidelity of the communications model throughout the competition to more closely align with real-world wireless communications, including line-of-sight behaviors. There are no plans to require pose or transform data to enable communications in the SubT Virtual Testbed. For specific reference to the C++ libCommsClient library, see https://bitbucket.org/osrf/subt/src/40ad8d39b7a2f1fd5e2a7b7eeff299ecd5188032/subt_gazebo/src/.

60. **Question:** Have you considered holding multiple (at least two) STIX events at different locations to make it more convenient for teams to attend (and therefore make it more likely they will attend)?
    Answer: Thank you for the feedback. We'll take another look into it pending additional and/or renewed interest (also noting that Competition Guidelines, Section 7 already offers "at least one STIX event").

61. **Question:** Where can we find a link to download the presentations that were made in the Mega Cavern on the 27th? Also, is there a list of the attendees and funded teams?
Answer: Materials from Competitors Day can be found on the SubT Challenge Website on the Resources Page (https://www.subtchallenge.com/resources.html), which includes the Competitors Day Contact List. A list of the funded teams can be found in the announcement on the DARPA website (http://www.darpa.mil/news-events/2018-09-26).

62. **Question:** I was trying to visualize the image topics in Rviz as described in OSRF SubT Rviz Wiki. When I list the ROS topic list, there is no image topic/rgbd published by x2 nor any other robots to visualize in Rviz. Is the OSRF SubT package still being improved?
Answer: For consistency and ease of use, The SubT Community Forum is a forum for rules, guidelines, or the competition process. Please ask questions pertaining to software, bugs, fixes, or enhancements to the SubT Virtual Testbed on the issue tracker https://bitbucket.org/osrf/subt/issues.

63. **Question:** Is the robot allowed to use internet or cloud connectivity?
Answer: DARPA does not plan to provide or allow the use of internet or cloud connectivity during the runs in the Systems Competition. Access to such resources are often limited in the field and in real-world scenarios following natural disasters. Teams with a compelling case for internet or cloud connectivity may propose such uses to DARPA for consideration.

64. **Question:** What information about a failed detection do we get back? If we find the right item, do we get to know that it is only the x-y-z location that is erroneous and that the detection is otherwise correct?
Answer: Additional details are expected to be released alongside a more detailed scoring function in the draft *SubT Challenge Rules* document expected to be released no later than nine months before the Tunnel Circuit.

4. Questions Answered as of November 26, 2018

65. **Question:** How many teams will be chosen from the qualification round? If one team qualifies for the Virtual Competition, can that team also qualify and compete in the Systems Competition?
Answer:
- Virtual Competition: DARPA does not currently intend to limit the number of teams that may qualify for the Virtual Competition. However, qualification requirements may be adjusted between events.
- Systems Competition: The number of teams that qualify for each Systems Competition event may depend, in part, on site availability and could vary across events. DARPA will make every effort to accommodate all teams that successfully qualify.

- Teams may qualify and compete in both the Systems Competition and the Virtual Competition. Participation in one of the competitions does not limit or guarantee participation in the other.

66. **Question:** What is the last date to qualify for the STIX event to be held in April 2019? According to the *SubT Challenge Qualification Guide* document, the last date to qualify for SubT integration Exercise #1 is December 21, 2018. Is that the last date to submit a submission, or is it the last date to hear back from the judges and already be qualified?
    Answer: The qualification deadlines listed in the *SubT Challenge Qualification Guide* document are the last date to submit a qualification submission for each event. DARPA intends to review and respond to teams as soon as possible. DARPA may elect to request additional information, discuss a team's submitted materials via teleconference, or arrange a site visit within the review period. Teams are encouraged to submit their qualification materials as early as possible.

67. **Question:** Regarding Qualification, should the mobile platforms be able to turn 90 degrees inside the 1.2m wide x 3m long passageways or is the 90 degree turn separate from the constraint passage?
    Answer: The ninety-degree turns do not need to be within the constrained passage portion of the qualification course.

68. **Question:** Can you please clarify the wording for UAV qualification "*The constrained passage should be no more than 1.5 m wide, no more than 1.5 m high, and at least 3 m long. Alternatively, teams with larger systems may demonstrate a constrained passage that is no more than twice as wide and twice as high as the maximum platform width.*" We want to qualify a DJI M210 (diameter: 1100 mm, height: 378 mm). Can you confirm a tunnel cross section for qualification is (2200 mm x 2200 mm)? We have had two other interpretations of 2x width and 2x height (i.e., 2200 mm x 756 mm), and one that took the max of the original and 2x (2200 mm x 1500mm).
    Answer: The constrained passage for qualification of a platform that is 1.1 m in diameter would be no more than 2.2 m wide, no more than 2.2 m high, and at least 3 m long.

69. **Question:** Regarding ground systems qualification, it says the platform should navigate to include dirt, gravel, and grass. Is one type of material sufficient or must it be all of the materials? Can the material part be separate from the autonomous navigation or must it be all in one autonomous run? Must the artifact detection be in the same run as the mobility or can it be separate?
    Answer: All three material types should be included in the mobility course and the course must be completed autonomously. The artifact identification task may be completed separate from the mobility task.

70. **Question:** Is it possible to provide a smaller prototype for the qualification round? According to the *SubT Challenge Qualification Guide* document, every team must submit a "narrative

description," and videos of the robot that performs the qualification tasks. Is it possible to submit videos of a small scale, prototype robot (0.5 ft x 0.5 ft) that can accurately perform all the qualification tasks in the 25 meter range (as required according to the qualification guide), or does the team have to submit a full-scale robot that would be able to function in the actual environment as well? In other words, are teams required to submit prototypes of robots to illustrate a part of the approach, or are they required to submit full-scale systems that they intend to develop further and use in the STIX event as well?

Answer: The mobile platforms used in the qualification submissions must be the same systems and overall technical approach that the team intends to use in each respective event. The "narrative description" may include the team's overall approach and development plan; however, the baseline performance of a submission will be based on the submitted videos. While teams may continue development after qualification, any significant changes in technical approach after initial qualification must be disclosed to DARPA and approved in advance of each event. Examples of significant changes could include different communications hardware, frequency bands, and/or platform type. DARPA may require additional demonstrations and/or safety inspections before a new platform type may be used in a STIX or Circuit Event.

71. **Question:** In the Virtual Competition is there any advantage to submitting the solution files early?

Answer: For the scored events, qualified teams will be provided a submission window (e.g., 1 week) in which their solution may be submitted for each event. It is not expected that there will be a significant advantage to submitting early within that window. DARPA is considering additional methods to incentivize earlier submissions to be run against practice scenarios in the months leading up to an event, possibly utilizing the leaderboard functionality within the SubT Virtual Testbed.

72. **Question:** Will DARPA use military VHF/UHF bands during the competition for logistics? Or will DARPA use commercial ISM bands?

Answer: DARPA is evaluating site-specific options for competition infrastructure with the goal of minimizing potential impact on teams, ideally with minimal/zero wireless footprint during scored runs. Additional site-specific details are expected no later than 3 months before each event.

73. **Question:** (Follow up to Question #14) How much will we know about what the artifacts look like in advance of the events?

Answer:
- DARPA intends to announce the expected artifacts in advance of each event as part of the finalized event rules (no later than three months before each event) so that teams know what they will be searching for. Where possible, DARPA intends to provide specific model numbers for teams to procure the same or similar items.
- For the Tunnel Circuit, an initial set of artifacts is expected to be announced no later than three months before the first STIX Event. DARPA may choose to adjust the final

set of artifacts for the Tunnel Circuit, in which case, the revised set of artifacts will be announced no later than three months before the Tunnel Circuit.

74. **Question:** Gas leaks and low oxygen levels will be an artifact that is spread over a large area. Are we expected to locate the source of the gas leak or will we instead report locations if we sense a particular concentration of gas/oxygen? When will the candidate gas types/concentrations be released?
Answer: DARPA is evaluating options for emulating gas/oxygen artifacts. In the event that the effect is spread over a large area, DARPA may 1) increase the accepted error bounds for detection of those artifacts, or 2) include an additional indicator (e.g., hazard sign) to serve as a reference point for localization. Additional details related to artifacts are expected to be released no later than 3 months before each event.

75. **Question:** Will the radio and cellphone artifacts in the qualification round be expected to be turned off or on? If a competitor wants to use the detection of cellphones and radios to qualify for the STIX or Tunnel Circuit, does the competitor's system have to detect the cellphone and radio when they are turned off, or on, or is it the team's choice?
Answer: For qualification purposes, teams may choose whether the artifacts are on or off. Whether the radio and cellphone artifacts are on, off, or dynamic may vary between each official event. Event-specific details will be released alongside the finalized rules for each event, expected no later than 3 months before each event. See also Question #73.

76. **Question:** Is there a list of candidate gases that may be released during a gas leak?
Answer: Please see Question #73 and Question #74.

77. **Question:** Will survivors be an accurate simulacrum, with features such as far infra-red emission, C02 emission, pulse, and movement; or will only a subset of features be modelled?
Answer: DARPA intends to emulate survivors as realistically as possible with the goal of supporting multiple sensing modalities. It is likely that thermal detection signatures will be supported. Additional detection signatures including auditory cues and movement are being considered. CO^2 emission and pulse are not currently under consideration, but teams are encouraged to request additional viable detection signatures for consideration.

78. **Question:** Will artifacts be in a continuous state, or will they change state during the challenge run? For example will a radio, gas leak, or pump turn on and off?
Answer: Depending on the event, the artifacts may be either in a continuous state or may change state within the run (dynamic artifact). Additional event-specific details will be released alongside the finalized rules for each event, expected no later than 3 months before each event. See also Question #73.

79. **Question:** According to the STIX qualification guide, competing systems need to be able to detect at least 3 artifacts as mentioned in the challenge guidelines. The challenge guideline

mentions "*Tools and fire extinguishers*", as well as "*Power Sources*", and "*Backpacks*", as 3 out of 10 possible DARPA SubT artifacts.

- In "*Tools and Fire Extinguishers*", do the fire extinguishers refer to the standard carbon dioxide fire extinguishers that are found in households and offices, or something else?
- Do the tools refer to hammers, screwdrivers, etc., or to something else?
- Will a submission be considered valid if the system in question can detect one kind of tool effectively in the demonstration video, but does not explicitly demonstrate its ability to detect another kind of tool?
- What do power sources refer to? Will we be required to detect wires with a current running in them, or a generator, or a charger of some sort, or something else?
- Are the backpacks required to be of a particular size or material, or are any arbitrary, valid backpacks acceptable?

In case DARPA is not able to clarify the above artifact details in question, would a submission be considered valid if a system is built on a team's interpretation of the artifact, since there are no strict guidelines or requirements stated in any DARPA SubT document?

Answer:

- For the purposes of STIX qualification, teams may select suitable artifacts based on their best reasonable interpretation. DARPA reserves the right to update the *SubT Challenge Qualification Guide* document to include more specific guidance regarding artifacts for future events.
- Standard household fire extinguishers are valid.
- Any common tools including but not limited to hammers, screwdrivers, toolboxes, and drills are valid. Teams are not required to demonstrate the ability to identify multiple types of tools.
- Power sources including but not limited to power outlets, electrical panels, generators, and chargers are valid. Teams may choose among any valid sensing modalities including but not limited to current sensing, visual, and thermal.
- Any standard backpacks are valid.

80. **Question:** Are we allowed to modify the robot models in SubT repository? If yes, what should we keep in mind while doing so?

    Answer: For official qualification or event submissions, Virtual Teams must use existing model configurations from the SubT Tech Repo. The use of custom mobility or sensor hardware models by Virtual Teams is not permitted, including but not limited to additional configurations of or modifications to the Universal Robotic Description Format (URDF) files supplied by the SubT Tech Repo.

81. **Question:** Regarding the Virtual Competition, what will be the size of each Tunnel Circuit course? For example, their overall length, width, height, etc.? Will the courses in the Virtual Competition be the same as the courses in the Systems Competition?

    Answer: DARPA intends to run Virtual Competition submissions against multiple unreleased Circuit Event Test Scenarios. The Virtual Competition test courses are expected to be similar in scale to the Systems Competition test courses but may not necessarily be identical. DARPA

intends to continue releasing practice scenarios within the SubT Tech Repo on an ongoing basis. These practice scenarios will be the best indication of what to expect in the scored Circuit Event Test Scenarios. Note that the Circuit Event Test Scenarios will not be released until after the respective Circuit Event has been completed.

82. **Question:** (Follow up to Question #8) Does the prohibition of physical intervention apply during the April STIX event? Would a team be able, or would DARPA personnel be able to intervene so that a partial failure does not terminate a test? Would we be able to substitute a human capability for a robot capability that is still under development? Specifically in our case we may not have our complete team of robots prototyped by April. An example of requested human intervention by DARPA personnel may be to substitute for a radio laying robot, with DARPA personnel manual dropping some witches hats (traffic cones) containing radio networking devices into the environment prior to the entry of the robots.
Answer: Teams will be encouraged to operate within the SubT Challenge Rules as the intent of the STIX Events is to provide teams with opportunities to test under competition-like conditions. However, some reasonable accommodations may be considered, provided safety and logistics concerns are addressed and approved in advance of the event. Specifically, for the example mentioned, DARPA would not support radio deployment over the entire course, but would likely support deployment over a reasonable section of the course for testing purposes.

83. **Question:** Regarding Emergency Stops,
    - What distance of operation, and time latency is required for the emergency stop capability?
    - Our current operating plan has robots continuing autonomous exploration should there be a failure on the communications link to the operators station. Must the emergency stop capability operate from the operator's console, precluding autonomous exploration by robots? If a robot is known to be exploring out-of-communications would it be satisfactory to provide an emergency stop hand-held unit that may be carried by DARPA personnel and provides tens of metres stand-off to activate emergency stops?
    - Should the emergency stop de-activate all robots or only a targeted robot?
    - If a hand-held emergency stop is acceptable, how many DARPA teams will be in the environment and how many emergency stop units should be provided?

    Answer:
    - The emergency stop capability must operate within the effective communication range of the system's communication architecture whether that is line-of-sight or beyond-line-of-sight. The platforms should be rendered completely motionless within 30 seconds.
    - Similar to your description, the "remote functionality" as described in the *SubT Challenge Guidelines* document is a portable system to aid in the recovery of systems outside of communications range of the base station.

- The emergency stop capability may be targeted to a specific platform, but should also provide the functionality to rapidly render all platforms safe. A team must be able to render all platforms completely motionless within 60 seconds.
- At least one portable emergency stop device will be required, but DARPA may request additional units for teams with numerous platforms.

84. Question: Can we guide the robot to enter inside the tunnel or cave so that it navigates inside the tunnel itself? Or should it be able to find the tunnel opening itself and navigate inside it after that?
Answer: Please see Question #18, and Question #19.

5. Questions Answered as of March 25, 2019

85. Question: (Follow up to Question 71) What if two teams have same score? On what basis will the winner be selected?
Answer: Please see Section 9.4 in the *SubT Challenge Guidelines* document (Revision 2) and the forthcoming draft *SubT Challenge Rules* document for information on tie breakers.

86. Question: What does it mean that the "course must be completed autonomously"? Can we provide way-points along the course, in advance of completing the course? Or is some kind of autonomous exploration strategy expected for the STIX qualification video?
Answer: The qualification videos are expected to demonstrate systems that can complete basic autonomous navigation (e.g., path planning, obstacle avoidance). Note that only sensors that are operational in subterranean environments may be used (i.e., no GPS-based waypoints). The course does not need to be so complex as to require an exploration strategy (e.g., minimal turns, no intersections).

87. Question: Regarding the qualification course and videos: Stops,
- Is artificial grass OK?
- For artifact detection, is a bounding box in a video feed sufficient?
- Are there any lighting requirements for the mobility video?
- By uneven terrain, are you looking for any slopes, or just traversal over dirt, gravel, and grass?
- Can uneven terrain be over a course segment vs. the complete course? Any requirements on size of segment?

Answer:
- Yes, artificial grass is permitted.
- Yes, a labeled bounding box is sufficient for demonstrating artifact detection.
- No, there are no lighting requirements for the mobility task. However, the artifact detection task does have lighting requirements.
- Slopes and more challenging uneven terrain are encouraged. However, teams are permitted to use reasonable discretion in building their qualification course based on the capabilities of their systems.

- The uneven terrain segments do not need to cover the entire course but should be long enough to demonstrate reliable movement over the terrain (e.g., several body-lengths).

88. **Question:** Is it possible to extend the existing configurations to include a configuration with two 2D LIDARs; one that is mounted horizontally (as it is now) and a second LIDRAR that is pointing down at an angle somewhere between 30 and 45 degrees? Several teams in Robotour (http://robotour.cz/) are now using this combination where the first LIDAR is used for obstacle avoidance and the second is used for road surface traverseability (to detect stones and holes). I am aware of SubT Challenge Guidance "Virtual competitors must use existing models from the SubT Tech Repo", but there is also a note about potential extensions. This question was originally posted at:
https://bitbucket.org/osrf/subt/issues/29/can-we-have-two-2d-lidars-configuration

    Answer: Thanks for the question and suggestion. We would be happy to consider such a configuration. The best way to submit a configuration for consideration is by building the proposed configuration and submitting it as a pull request to the SubT Tech Repo at https://bitbucket.org/osrf/subt/pull-requests/. Please note that no guarantee is provided that such requests will be approved. Any new models will need to undergo review and validation before being included in the repository. Note that a model contributed by a team, if found viable and deemed appropriate for the spirit of the competition, will be made available to all teams through the SubT Tech Repo.

89. **Question:** Is there an official list of ROS sensor and control topics that solutions will be restricted to using for the competition? For example, there is a small list on the API page here:
    https://bitbucket.org/osrf/subt/wiki/api

    Which is noticeably missing things like the raw_image from the RGBD cameras. There are also a number of other topics available in the actual simulation, (notably odometry/pose information, trajectory commands, etc…) for example:
    /X4/air_pressure
    /X4/cmd_vel
    …
    /X4/select
    /X4/wind_speed

    Knowing which of these will and will not be available for use for each platform in the virtual track competition will have a large impact on potential solutions.

    Answer: All published topics corresponding to vehicle control and sensors are accessible by the vehicle to which they correspond. For example, the X4 can access any topic published with the /X4/ prefix. Robots will not be able to subscribe to topics published by other vehicles. Gazebo world topics such as /tf/ will not be useable by teams in the competition. Communication between robots will be isolated to the SubT communications plugin.

90. **Question:** Is there a plan to have a STIX-like event for the Virtual Competition in April 2019? For example, we could exercise deployment of Docker images, test the scoreboard, etc. I

probably misunderstood that 21st Dec 2018 was the deadline the Systems Competition and the Virtual Competition, but it now seems that the deadline was only for the Systems Competition, correct?

Answer: Your description is correct, the December 21, 2018 deadline was for submitting qualification materials for the April 2019 STIX Event which is intended only for Systems Competition participants. However, virtual qualification materials are also being accepted on a rolling basis and will be valid for participation in the Virtual Tunnel Circuit Event in August 2019. Thank you for the suggestion, we are considering options for a similar STIX-like event for the Virtual Competition and will be releasing more information in the coming weeks.

91. **Question:** Virtual Track Controller Isolation: Will the SubT Virtual Testbed enforce isolation between controllers? Currently, any one of the robot controllers can view sensor data and/or command any other robot - which seems counter to the spirit of the challenge. Will isolation be enforced for the competition?

    Answer: All published topics corresponding to vehicle control and sensors are accessible only by the vehicle to which they correspond. Isolation will be enforced in submitted competition solutions, so competitors should not attempt to bypass the communications plugin.

92. **Question:** For the official competition events, are we required to use the networking model provided through the Virtual Tech Repo or should we implement our own separate networking code for multiple robots to communicate with each other?

    Answer: Virtual Competition teams will be required to utilize the SubT communications plugin for all inter-robot communication for competition purposes. The communications plugin will continue to be updated and improved throughout the competition.

93. **Question:** Is there a way to edit questions that have already been posted to the SubT Community Forum?

    Answer: Thanks for the suggestion! We have updated the permissions so that you should now be able to edit your previous posts. You are also welcome to follow up on any post by replying within the same thread. We are currently reviewing all new posts, so there might be a slight delay before it appears.

94. According to the Challenge Guidelines (as well as a few posts on this forum), further details about the interface for reporting artifacts at the STIX event were to be released no later than 3 months before the event. That deadline has since passed - would we be able to get an updated release date?

    - "*The ICD is expected to be released no later than three months before the first STIX Event.*"
    - "*Artifact reports are expected to be transmitted to the DARPA Command Post over an Ethernet link from the team operator station. The detailed format, protocol, and example implementation will be released in an upcoming Interface Control Document (ICD).*"

Answer: Thanks for closely tracking the schedule and for the interest in the Interface Control Document (ICD). We are actively working to get the ICD released as soon as possible. Notifications of the release will be posted to the SubT Community Forum in the Announcements category.

95. **Question:** One of the lines in the STIX event documentation states the following (from Section 2):

   "*For the three-hour and two-hour time slots, the mine will be split into two sides. Teams will have the opportunity to test on each side during one of these two practice sessions.*"

   However, the schedule splits Day 2 into multiple 2.5 hour practice sessions. Should we expect to have a 3 hour session available and plan accordingly (namely for battery budgets / maximum operating durations)?

   Answer: Thanks for catching that. The correct duration is reflected in the schedule. Each of the two practice sessions will be 2.5 hours in duration. As it relates to battery budgets, note that we will allow teams to change batteries as needed within the practice session. We will work with teams to make the practice sessions as beneficial for testing as possible.

96. **Question:** According to the Challenge Guidelines (as well as a few posts on this forum), further details about the artifacts present at the STIX event were to be released no later than 3 months before the event. That deadline has since passed - would we be able to get an updated release date?

   "*For the Tunnel Circuit, an initial set of artifacts is expected to be announced no later than three months before the first STIX Event. DARPA may choose to adjust the final set of artifacts for the Tunnel Circuit, in which case, the revised set of artifacts will be announced no later than three months before the Tunnel Circuit.*"

   There are a number of things we are hoping to learn from the document including, but not limited to, in no particular order:

   a) Which orientations are possible for artifacts? Specifically, should we largely be considering "reasonable / natural" placements (e.g. on the ground, on ledges, leaning against something)?

   b) Where possible, which model (or model number) of artifacts should we be identifying? This is especially important for artifacts which span multiple distinct items, such as tools, gas leaks (what type of gasses), ingress / egress points, etc.

   c) Will artifacts that can be turned "on", e.g. electric pumps, radio / cellphone, be on?

   d) How realistically will survivors be emulated? An earlier answer stated that thermal detection is likely to be supported, but was not specific about auditory signals and movement.

   e) How dynamic will artifacts be? Should we expect to have to return to objects at a later time (e.g. a gas leak starting half way through our run, in a section that has already been explored by a robot)?

   f) What criteria have been finalized for gas / oxygen artifacts? Has DARPA decided to increase error bounds, add an additional indicator, or something else? What range of concentrations should we expect? Which types of gas will be present in gas leaks?

g) An earlier forum post stated that "DARPA may choose to utilize automated methods of implementing dynamic obstacles", with another saying that "it is expected that artifacts will be reasonably secured as to not fall or move within a single run." With (significant) movement of artifacts not being expected, which other types of dynamic behaviors of artifacts can we expect?

h) How many total artifacts will we need to detect?

i) Detections will be reported as an (x, y, z) location, as well as a category. Which point on the artifact is the reported location expected to correspond to (e.g. center, arbitrary point on object, arbitrary point within bounding box, location where object touches ground, etc.)?

Answer: Thanks for closely tracking the schedule and for the excellent questions. We are actively working to get the Artifact Specifications document released as soon as possible. Notifications of the release will be posted to the SubT Community Forum in the Announcements category. Please see answers to each of your questions below:

a) Yes, you can expect the orientations of artifacts to be "reasonable / natural" placements.

b) Specific model numbers of each artifact (to the extent possible) will be provided in the specifications document.

c) The operational state of each artifact will be provided in the specifications document.

d) Additional details will be provided in the specifications document, but we expect the survivor artifacts to have thermal signatures. We do not currently plan on survivors with auditory signals or movement, but may adjust based on testing at STIX and feedback from the teams.

e) The current plan for the artifacts is for their state to be consistent throughout the scored runs (e.g., gas leak is always leaking). However, DARPA reserves the right to adjust how dynamic artifacts may be in later events as the competition progresses.

f) DARPA is evaluating a number of alternatives for gas / oxygen artifacts and hope to release specific details as soon as possible.

g) The use of dynamic obstacles (e,g., closing door, falling debris) is distinct and separate from dynamic artifacts (e.g., articulated survivor). Artifacts are not expected to change locations but they may incorporate motion (e.g., rotating motor or living limb).

h) DARPA anticipates a total of nine artifact types, with an initial set of five to be specified for the STIX event in the first release of the specifications document.

i) The origin point of each artifact will be provided in the specifications document.

97. **Question:** While interfacing with the transponder will not be required for the STIX event, the transponder will still be attached to the robots. What size and weight should we expect from the transponder, to budget accordingly (particularly on flying platforms)? Additionally, which frequency should we expect the transponder to operate on?
    Answer: We are working to keep the size and weight as low as possible to limit impact and burden on teams. To provide a rough approximate estimate of an upper bound, the transponder is expected to be approximately 70 mm x 50 mm x 30 mm and approximately 40

grams. The final specifications are subject to change based on testing at STIX. We are evaluating multiple options, additional details related to frequency will be released soon.

98. **Question:** It would be great if the reference frame fiducials would also include 3D geometric fiducials to allow alignment from 3D LiDARs. Examples would be balls, cylinders, boxes, or could even be the gate itself.
Answer: Thanks for the suggestion. We do plan to provide specifications on the starting gate dimensions and geometry which could be used with 3D LiDARs for alignment. Any other specific requests or suggestions are welcome.

99. **Question:** (Follow up to Question #49) I was wondering whether DARPA would consider a reporting scheme where each team can report a model as soon as it is detected with whatever the pose estimate is at that time. Then they would be allowed to submit a second, refined pose estimate for that artifact later - with some appropriate scoring scheme that considers accuracy and time. That would allow you to separately gauge the time at which artifacts are detected from the time at which the localization is refined. Currently teams may choose to withhold artifact reports until the position is more certain which may be quite a bit after first contact.
Answer: Thank you for the suggestion! We did consider a number of alternate scoring criteria, some of which included separate evaluations based on accuracy and time as you suggest. In the current artifact reporting scheme, teams have enough report attempts relative to the total number of artifacts to allow for both an early report and a later report with a refined location estimate.

100. **Question:** Our team is planning on participating in the Tunnel Challenge in August. Is it possible to be able to do a walk-through of the mine on the 3rd Day Course walking tour? Will there be any video of the course or results made available to the public or teams?
Answer: Unfortunately, only qualified teams will be able to participate in the STIX Event which includes the walking tour on Day 3. We do not anticipate releasing results of the event as it is intended to be a non-scored integration exercise. Nevertheless, we do hope to release some course materials from the STIX Event as public resources for all teams to access. Based on your request, we will consider including a video walk-through in those materials. Please note that the location of the Tunnel Circuit has not yet been announced, but is not expected to be the same location as STIX.

101. **Question:** I was wondering if you had any insight into the exact dates the tunnel circuit event will be held in August?
Answer: The Tunnel Circuit is tentatively planned for the period of August 4-24th, exact testing dates and duration will be released in the Operations Guide which is expected to be released 90 days before the event.

102. **Question:** (Follow up to Question #101) 90 days before is very insufficient. Everybody has/wants to plan summer holidays in some ways, and that is a thing that can't be done 90

days in advance. Is there a possibility that you decide about this earlier - say, at the beginning of May?

Answer: The 90 day timeline is necessary to provide time for teams to qualify for each event. However, as the Tunnel Circuit is planned for August 4-24, it is expected that the specific dates and duration for each qualified team will be announced at the beginning of May as suggested.

103. **Question:** Thanks for releasing the STIX Interface Control Document. Would it be possible for you to release a "test server" or "test command post" that we could run on our desktop (or have you run it on some IP address) and see if we are sending the right messages prior to STIX? All I am after is a simple scoring or map endpoint that could say if the message was malformed etc. This would be one less thing to worry about on the day and could potentially save a fair amount of time when we are all there.

Answer: Thanks for the suggestion. Yes, we do plan to release a test scoring server with an anticipated release date of March 8. Upon release, an update will be posted in the Announcements category.

104. **Question:** Will the teams be expected to create our own code for sending the http messages or will an API be provided by DARPA? Additionally, will a simulator be provided for the DARPA command post so we can test running our system and receive the same feedback as in the STIX/competition?

Answer: We do plan to release a test scoring server with an anticipated release date of March 8. We also intend to release sample code for sending http messages. Upon release, an update will be posted in the Announcements category.

105. **Question:** (Follow up to Question #98) Any updates on the Fiducial layout? Some additional questions/comments we have around the orientation:
    a) Could you please make the 'z' axis gravity aligned? (i.e. can we use our own IMU to estimate the z axis).
    b) Will the "orientation vector" be able to determine the yaw and pitch, or is it only usable for yaw?

Answer: We are finalizing the design and plan to release more details no later than March 8. The basic design will be similar to the description provided in Section 9.3.2 of the *Competition Rules Tunnel Circuit (Draft)* document. Based on feedback collected from teams, we plan to add additional retro-reflective fiducials and ensure that the gate has a solid structure to enable its use as a 3D geometric fiducial.
    a) Yes, the "z" axis is expected to be gravity aligned.
    b) The orientation vector will essentially define the y-axis vector (as illustrated in Figure 6 of Section 9.3.2). The z-axis will be gravity aligned. And the x-axis will be perpendicular to the other two axes based on a right-handed coordinate frame. The x,y,z coordinates of the visual and laser fiducials will be provided to further facilitate alignment to the DARPA coordinate frame.

106. Question: Is there more information available about what the starting gate will look like, or what fiducials will be present at the STIX event for us to align our maps with the DARPA coordinate frame? We would like to begin development of the alignment algorithms, as well as deployment and testing as soon as possible. If the information on the starting gate isn't available yet, should we construct our own and present it to DARPA at the STIX event?
Answer: Please see Question #105.

107. Question: Can DARPA also mount retro-reflective markers/fiducials at the starting gate to aid in global map alignment for teams using 3D LIDAR?
Answer: Thanks for the suggestion, we will plan on having retro-reflective fiducials for LIDAR-based sensing approaches. We welcome specific recommendations for consideration.

108. Question: (Follow up to Question #74) As a follow up do you have any guidance regarding the types of gasses that may be used: volatile organics, carbon monoxide etc. We are contemplating different sensors for this task and it would be useful to know what range of gasses are likely.
Answer: No additional information is available at this time. We expect to release additional information related to potential gas/oxygen artifacts by May 1, 2019.

109. Question: Can DARPA provide upper and lower bounds on the expected distance between the command center and where autonomous vehicles start and also the command center and the mine entrance for the STIX event?
Answer: At STIX, teams will operate their systems out of the base station that is planned to be located within 7-10 m of the Staging Area. The distance between the Staging Area and the mine portal is also planned to be 7-10 m. The layout of each of the mine portals at STIX is slightly different, so the range from the base station to mine portal is 10-25 m. Please note that these distances are the approximate distances as planned and may shift slightly upon setup of the infrastructure.

110. Question: As specified in the Interface Control Document (Section 6.3), it is possible to compress maps data array. Is it also possible to compress the entire body of the http request using the Content-Encoding header? .e.g., Content-Encoding: gzip
Answer: Yes, teams may compress the body of the http request using "content-coding" values of:
- 'identity' (the default that will be assumed if not specified)
- 'gzip' or 'x-gzip'
- 'deflate'

These are specified in RFC 7231 (https://tools.ietf.org/html/rfc7231#section-3.1.2.1). Only these encodings will be supported (e.g., the 'compress' LZW algorithm will not be supported).

111. **Question:** (Follow up to Question #98) As mentioned in the [Competition Rules Tunnel Circuit (Draft)](#) document, the orientation vector will be defined by a line. Are you going to release any specifications for this line drawn on the ground e.g., width, color, etc.?
Answer: Please see the [Reference Frame Fiducials Update](#) post for an updated description of the starting gate and reference points. In particular, due to the possibility of an uneven staging area floor at different test sites, we have decided to define the orientation vector with two discrete reference points that are marked by two survey markers.

112. **Question:** (Follow up to Question #98) Is there a reason that DARPA frame is defined as to not follow the ROS convention (x-axis: forward, z-axis: up) given the virtual test bed is in ROS?
Answer: Thanks for the suggestion. The orientation for the DARPA-defined reference frame was originally selected to align with the Easting-Northing convention commonly used in surveying. However, we will make the adjustment as you suggest to follow the ROS convention in order to maintain consistency between the Virtual and Systems Competitions.

113. **Question:** (Follow up to Question #98) Could we also suggest a visual fiducial of our own design? If so, how can we go about that?
Answer: Suggestions are always welcome and can be submitted for consideration to the SubT Challenge email inbox (subtchallenge@darpa.mil).

114. **Question:** (Follow up to Question #98) This might seem like a somewhat esoteric question, but I am looking at how to align the bot's reference frame with DARPA's and came to a question. The origin of the question has to do with the required accuracy. The cumulative course length is 4 to 8 km. I might project the furthest extent from the fiducials might be 1 km (not defined, just a guess). Since artifacts need to be located to within 5 m, that means that we must stay aligned to DARPA's reference frame to at least a quarter of a degree (preferably tighter than that). (Someone please correct me if I have missed something or have the math wrong).

You have defined the z-axis as aligned with gravity (and hopefully the fiducials are tightly aligned with that). The y-axis is defined with an orientation vector perpendicular to the fiducials (still your jobs to orient that accurately). However, unless that starting area is flat and level, it probably will not line up perpendicular to the defined z-axis (quarter degree level is somewhat challenging over an area). I would assume that the vector is providing a direction, but the actual reference frame is perpendicular to the z-axis with the zero for all three axis being at the center point along the base line along the bottom of the front of the fiducial gate, but in the direction indicated.

As you said above, the x-axis is the perpendicular to the y-axis and z-axis. I am assuming that the bot should default to that definition of x-axis rather than the line connecting the base of the fiducial structure (though ideally those are identical).

While I know this is somewhat esoteric, but I am trying to define the best definition of how the bot should align itself to the DARPA reference frame.

Answer: The origin is defined by a survey marker that is set at (0, 0, 0), and the orientation is defined by a second marker that is at approximately -5 m in the x-axis, exactly 0 m in the y-axis (by definition), and approximately 0 in the z-axis. The exact z-axis coordinate of the orientation marker may be positive or negative and is dependent on the terrain of the staging area.

115. **Question:** The Reference Frame Fiducials Update refers to some distal fiducials that are set at 25m along the x-axis into the course. The example tables specifically do not provide any y or z position information, limiting the amount of orientation to the DARPA reference frame. Is this the intent and what will be implemented? And I assume all coordinates are given in meters.

Answer: Thanks for the clarifying question. The x, y, and z coordinates of all reference points will be provided to teams, including the distal fiducials. The y-axis and z-axis coordinates of the distal fiducials is dependent on the topology and terrain of the site, so listing a notional coordinate could have been misleading. The "~" values in Table 1 of the document are intended to convey that the distal fiducials may not necessarily be directly aligned with the x-axis in front of the Starting Gate. All coordinates in the table and figures are in meters.

116. **Question:** Will the level of ambient lighting in the area around the starting gate be defined?

Answer: The level of ambient lighting in the staging area will vary based on the day and time of day of any given run. LED work lights will be placed in the staging area to provide additional illumination. No additional lighting is expected to be provided for the distal reference points, which in some cases may be in complete darkness.

117. **Question:** (Follow up to Question #109) Could I please clarify:
    - "base station" is one team member controlling the robots from a user interface, with many DARPA and other observers watching.
    - "Staging Area" is the other half dozen team members preparing robots for entry to the circuit, replenishing robots that exit the circuit.

For example, a scenario that I could imagine: The base station person will instruct a robot to exit the course, the base station person informs the Staging Area personnel that the robot requires new batteries (how ? do they just yell, or can we have information interfaces (and control interfaces?) in the Staging Area?), the Staging Area personnel change the robot batteries, the Staging Area personnel inform the base station person that the robot is ready to go (the status will appear on the user-interface, but is this sufficient for OHS?) and the base-station person commands the robot to enter the course.

Answer: The "base station" is the computer interface that communicates with the deployed systems and relays artifact reports and map updates to the DARPA Command Post. Teams are permitted to have a single "human supervisor" at a base station. Teams are also permitted to have a "pit crew" that may operate within the Staging Area. The pit crew may

assist with operations tasks such as deploying the systems, performing repairs, and changing batteries. Please see Section 9.2 of the Competition Rules Tunnel Circuit (Draft) document for more information related to Staging Area personnel.

At STIX, DARPA is providing teams two options for their base station location. The first is a 20' x 8' trailer that is being provided near the Staging Area to provide teams a weather-sheltered area. Teams may also locate their base station at a 6' x 30" table located inside the 20' x 20' tent covering the Staging Area.

In either case, the human supervisor at the base station may communicate with the pit crew by voice or radio communication. Teams are responsible for providing their own radios.

118. **Question:** In the Artifacts Specification document, it states that the common artifact 2 (Cell phone) will have all of its internal radios enabled. WiFi on Android phones uses only passive discovery mode so it won't transmit anything out unless it is set to (access point) AP mode. Will the phone have access point mode activated (WiFi hotspot)?
Answer: The cell phone will be running in "Hotspot" mode and thus the WIFI radio will be operating as an access point. Each cell phone artifact will broadcast its SSID over WIFI, which will be in the form of "PhoneArtifactXX" where XX will be a two-digit randomized number. The cell phone access point will employ WPS encryption and will not accept connections from team platforms.

6. Questions Answered as of August 13, 2019

119. **Question:** What are the specific keyword strings for reporting the artifact types? With spaces and lower-case letters?
Answer: The released test scoring server does not distinguish based on artifact type. It simply returns canned data if the format is correct. The competition scoring server will accept keyword strings as in the section headers of the Artifacts Specification STIX Event document (i.e., capitalized words with spaces as necessary). See below for the set of competition artifact type strings:
["Survivor", "Cell Phone", "Backpack", "Drill", "Fire Extinguisher"]

120. **Question:** The Artifact Specification document specifies that all the radios on the cell phone will be on. Does this mean that Bluetooth will be on as well? If so, will the phone be set to discoverable mode when playing video / audio? We've been trying to detect devices via Bluetooth and are successfully able to detect other Android devices (e.g. One Plus 3T) even when they're locked. However, the Galaxy J8 seems only be discoverable when inside the Bluetooth menu. If the phone is intended to be discoverable at all times, are there any particular settings that need to be configured?
Answer: We are using an Android app that puts the Bluetooth radio in Discovery Mode for an unlimited amount of time. There are several free apps available on the Google Play Store

that teams may use to turn on Bluetooth Discovery Mode for a specified interval of time. See also Question #118.

121. **Question:** What is the correct way to propose a new robot configuration by using 2 cameras and when will there be a feedback about the request? We asked for a new robot configuration by raising a pull request with the changed robot description at the SubT Tech Repo on the 28th February. We want to use this configuration also for the qualification. So we would appreciate any feedback on our pull-request. So that we know whether we still have to change something.

    Answer: Sorry for the delayed review, but your pull request has been merged and reviews are expected to happen faster in the future. Additional configurations of existing models to the SubT Tech Repo will be evaluated following the submission of a pull request to https://bitbucket.org/osrf/subt/pull-requests/. Feedback will be discussed in the comments of the submitted pull request. Note that DARPA may choose to merge or decline a submitted configuration based on configuration utility, code quality, similarity to existing configurations, or other factors. The configurations that are selected to be merged will be made available to all competitors through the SubT Tech Repo and will be eligible to compete in qualification and DARPA SubT Virtual Challenge events.

122. **Question:** I think there may be a problem with the positions defined in Table 4 of Rev 2 of the Competition Rules Tunnel Circuit (Draft) document. It appears the y-axis in Table 4 is the reverse of the axes defined in Figure 6.

    Answer: Thanks for catching this. The y-axis values in Table 4 of Rev 2 should be reversed. We will make the correction in the next release of the document.

123. **Question:** Can we assume that the April tags will be mounted in the canonical orientation (i.e. x to the right, y up, as viewed from the front)?

    Answer: The AprilTags are being mounted in the orientation shown in Figure 8 of Revision 2 of the Competition Rules Tunnel Circuit (Draft) document.

124. **Question:** While trying out the Test Scoring Server provide by DARPA we noticed that when submitting artifacts from a browser, we are getting a cross origin request error CORS. We were assuming that DARPA server would have "Access-Control-Allow-Origin": "*" in its response header. Is that the case for the real server?

    Answer: The Competition Scoring Server will include Access-Control-Allow-Origin": "*" in the response header.

125. **Question:** So when DARPA mentions making it easier to navigate urban environments etc. they are not talking about first responders who would be down there looking to rescue potential victims?

    Answer: The primary scenario of interest for the competition is providing rapid situational awareness to a small team of first responders preparing to enter unknown and dynamic subterranean environments. The environments present significant dangers that could

preclude employing a human team, such as collapsed and unstable structures or debris, presence of hazardous materials, lack of ventilation, and potential for smoke and/or fire. No (human) team members are permitted to enter the test course during the competition, but the technologies being developed for the competition could be used by first responders to better inform follow-on operations.

126. **Question:** At the STIX event, our team was supplied with an Infrastructure Info document which contained the most up-to-date/detailed position information of reference points relating to the DARPA reference frame. Can this document be added to the resources page? Can the side length of the square AprilTags be added to the document as well?
Answer: The STIX reference point coordinates will be released soon along with several additional STIX reference documents and datasets. The AprilTag targets are in the 16h5 family, printed at a size of 12" x 12" (so that the black border is 9" x 9"). See the [Competition Rules Tunnel Circuit (Draft)](#) document for additional details related to fiducials.

127. **Question:** Our institution requires us to implement wireless emergency stop for operations in mines. Can you please provide details of the exact wireless module that you use for the Tier 2 recovery emergency stop capability?
Answer: We are planning to provide the hardware and software design files for the handheld Tier 2 emergency E-Stop transmitter. These files will be released along with several other data and design resources in the coming weeks.

Teams may also choose to instrument their test course with one or more stationary E-Stop transmitters using the same XBee radio that is in the handheld transmitter. The stationary XBees in the test course can operate on a mesh network to broadcast the e-stop signal. This likely requires line-of-sight for each hop in the mesh network. A single transmitter (whether handheld or stationary) would thus propagate the e-stop signal broadcast throughout the mesh network.

With the XBee transmitter in API mode, the following hexadecimal packet can be sent to the XBee transmitter via serial to initiate a broadcast of the emergency stop signal:
0x 7E 00 10 17 01 00 00 00 00 00 00 FF FF FF FE 03 44 31 05 6F
This packet should be continuously rebroadcasted at 1Hz during an emergency stop state.

Refer to the [Transponder and Emergency Stop Integration Guide](#), especially the Configuration section in Appendix A, for helpful details on XBee radio configuration and usage.

128. **Question:** Is there still an opportunity to participate in the SubT Challenge Tunnel Circuit (Systems Competition) if our team did not qualify in time for the April 22 deadline? Is there a way to partner with an already qualified team to provide them access to our component technologies?

Answer: You are welcome to partner with any other teams participating in the SubT Challenge. The teams that participated in the STIX event in April are already public. We expect to release the list of qualified teams for the Tunnel Circuit in the next few days. You are welcome to reach out to those teams to discuss partnership opportunities. You may also consider posting a capability description to the SubT Community forum (https://community.subtchallenge.com/t/about-the-teaming-category/16).

Please note, teams that have already successfully qualified are permitted to add new platforms, but will have to submit platform-specific qualification materials by July 1 to use them in the Tunnel Circuit. These materials include technical and safety documentation, e-stop qualification videos, and Handling Manuals.

129. **Question:** There is a pull request with branch "virtual_stix". Is it planned to be used for a "Virtual STIX" or it is example of tunnels in Idaho Springs only? Is there a chance to have identical positions of artifacts as in System Track?
Answer: The intent of this new world model and scenario is to serve as a "Virtual STIX", to provide another scenario that can be used for qualification purposes, and to support the SubT Autonomy Tutorial being hosted at ICRA 2019. The tutorial will leverage this new scenario, but it is also available for the entire SubT Community regardless of participation in the ICRA tutorial. This is the same scenario that is referenced as the "ICRA Scenario" in this announcement. We do not intend to have the artifacts in the identical positions that were used in the Systems Competition STIX event.

130. **Question:** Is it expected that the public will be able to attend/view during the tunnel circuit event?
Answer: The Tunnel Circuit Event will not be open to the general public. We do, however, expect to release information and media before, during, and after the event to keep the public apprised of the competition efforts.

131. **Question:** Are slides or videos of the tutorial available for those who were not able to attend?
Answer: We anticipate slides will be available on the workshop website http://icra2019subt.info/.

132. **Question:** Will DARPA release raw video from Edgar Experimental Mine for future research? Such raw video will provide excellent tool for benchmarking and practical research reference point for various current and future methods of object identification/recognition and possibly localization in complex environment. As suggestion/crazy idea, best raw video feed would be recorded using dual 360 cameras at approximately one meter per second speed, this would allow to not only simulate various fields of view, and gaze's, but additionally calculating moving parallax, binocular vision and much more.

Answer: We anticipate releasing the raw video from Edgar as part of a more comprehensive dataset release soon. Physical and virtual walks through of the Edgar Experimental Mine have been released. Links to those videos are available below.
STIX Tunnel Tour: https://www.youtube.com/watch?v=Z5Tryqg36ww
Edgar Point Cloud Flythrough: https://www.youtube.com/watch?v=jJoc3oQ3Bo8
Virtual STIX Flythrough
https://www.youtube.com/watch?v=ZZuT6HhpIJI&feature=youtu.be

133. **Question:** The Artifact Specification document specifies the model number J819M/DS for this Samsung phone. This model doesn't seem to exist. Also the link to Amazon.com goes to a page selling the J810M/DS. Can you please confirm if you meant J810M/DS?
Answer: The model for the cell phone artifact is J810M/DS.

134. **Question:** As mentioned in Tunnel Circuit Operations Guide, DARPA will provide utility vehicles to support transport from Team Garage to course Staging Area. Since we are using floating robots with Helium, is it possible not to flat the robots from run to run and transport the robots by manually caring them? Also, if the robots are inside the tunnel while the run comes to an end, is it possible that DARPA help retrieve the robots without flatting them? By doing so, we can save the amount of Helium wasted and also some time from re-inflating them.
Answer: The DARPA team will work with teams to safely and effectively move your helium-based robot to and from the Staging Area. Team members are not allowed past the staging area in the course tunnel. Teams will provide a safety handling brief to the DARPA staff prior to the run to discuss safe handling of the robots. If at the completion of the run the robot does not return back to the Staging area, our field team will retrieve the asset with safety taking precedence over conserving resources. Please plan to have enough supplies to support multiple runs over the week.

135. **Question:** Do you already have some information about how the virtual competition in the tunnel circuit will take place?
Answer: The qualification for the Virtual Competition is June 10. We anticipate releasing additional information on timeline and specifics shortly after qualifications are finalized.

136. **Question:** Is the Point Cloud from the Edgar Point Cloud Flythrough video available for download?
Answer: We do anticipate releasing the Edgar point cloud data as part of a more comprehensive dataset release soon.

137. **Question:** The artifact survivor's position is stated as "static sitting position against walls…" in the *Artifact Specification* document. In the STIX Edgar mine setup, one of the artifact survivors was lying down on the ground. Is this lying-down a possible survivor position in the competition course?

Answer: The survivor artifact will be in a sitting position for the Tunnel Circuit events, in both the Virtual and Systems Competitions. We may add additional configurations or adjust the position of artifact in future events.

138. **Question:** I was curious if the cloud simulation environment will be available for competitor use between now and the virtual track tunnel circuit submission deadline? Just trying to figure out if I should start setting up a larger-scale simulation environment or if there will be a way to make use of CloudSim for pre-submission testing?
Answer: We are planning to release a few representative practice scenarios that teams will be able to use to test the cloud submission process and also confirm that their submissions are performing as expected. The practice scenarios will be released on approximately July 1.

139. **Question:** Section 8.6 of the SubT tunnel circuit rules regarding mapping which states that map updates should be provided at a rate of one update every 10 seconds. During a run it may well be the case that all of the robots that are exploring and discovering new aspects of the scene may be temporarily disconnected from the operator station for periods that exceed 10 seconds. During those periods there may not be any new map updates. In other words there may be a tension between exploring new areas of the tunnel and trying to maintain comms to report map information to the base. Should we continue to send empty updates or resend map fragments that we may have already sent during periods where we have no new information to report?
Answer: Please see Question #23.

140. **Question:** (Follow up to Question #135) Does that mean the deadline has passed for qualification and registration?
Answer: Yes, the qualification deadline for the Tunnel Circuit has already passed; however, teams may continue to submit qualifications on a rolling basis for future competition events. Please see the *Qualification Guide* document for additional details and deadlines.

141. **Question:** The schedule for the tunnel circuit has four days of scored runs with a "working day" in the middle. We have several clarifying questions:
    - Will each team be scheduled on one day for its scored run or multiple days?
    - Is there a practice tent and/or tunnel on site like at STIX?
    - How far in advance will we find out which days we're scheduled on?
Answer: Please see the latest revision of the *Tunnel Circuit Operations Guide* for an updated and more detailed schedule.

142. **Question:** Are teams permitted to use the DARPA-provided Tier 2 E-Stop as a side channel for low-bandwidth communications? For example, heartbeats or simple commands.
Answer: No, the DARPA provided units should only be used for DARPA transponder and Tier 2 E-Stop communication. Ideally, teams would only monitor the assigned pin via direct connection for an e-stop condition and act accordingly. In the case of USB connection

methods, no traffic should be transmitted under any circumstances via the E-stop device. There are safety and fairness implications in using Tier 2 E-Stop components outside of these parameters. Any additional communications, including heartbeats or simple commands, are considered outside the spirit of the program.

143. **Question:** We've already implemented the Tier 2 e-stop on our platform. Both the design documents and real behavior say that once the E-Stop command is broadcast, it doesn't get cleared from the receivers even if the broadcasting stops. The implementation guide then tells that there is a command for clearing such stale E-Stop command. This also works for us. The question is, if DARPA personnel will ask us during the mission to clear the stale E-Stops, how do we do it on platforms which are out of reach of our communications technology?
    Answer: After an emergency stop has been triggered, DARPA Competition Staff will manually extract all platforms from the course. Once the platforms are removed from the course and relocated to the Staging Area, teams may clear the E-Stop states. In select cases, DARPA recovery personnel may opt to re-enable one or more platforms for remote controlled extraction. In these situations, the DARPA Competition Staff will work with the team on a procedure to safely re-enable their systems.

144. **Question:** The competition scenarios are going to be more like "Virtual_stix", with the complex layout, or more like the Tunnel_circuit ones which are similar to the qualifying map?
    Answer: The three released tunnel practice worlds are approximately representative of the virtual competition scenarios in construction, scale, and complexity.

145. **Question:** Will there be the facility for extra team members to attend the event. Specifically, our team is larger than the 20 people registered with DARPA. Can these extra people enter the site at the Bruceton mine and enter the team garage?
    Answer: No, teams are restricted to 20 registered team members for the Tunnel Circuit.

146. **Question:** The rough terrain is one of the main focus in the SubT challenge. However in the concern of safely operating and preserving the completeness of the robot, could we expect that there's no sudden cliff (>70 degree) that if a UGV is not aware of, the falling of the robot may cause serious damage? Or is it part of the challenge that our robot should definitely be aware of?
    Answer: Terrain elements and obstacles may include constrained passages, sharp turns, large drops/climbs, inclines, steps, ladders, and mud, sand, and/or water. Please see the Tunnel Circuit Environment Preview for a representative, though incomplete, preview of the Tunnel Circuit courses.

147. **Question:** Can teams have another set of communication module (i.e. Xbee-Pro 900HP) on the robot that a set is purely for Tier-2 Estop and another is for our own communication purpose?

Answer: Teams may use their own set of XBee radios for communication alongside (and separate from) the DARPA transponder XBees. If the team's separate set of XBees operate on the 902-928MHz ISM band, they must use a Preamble ID that is different from the DARPA transponder's Preamble ID (0x03). If the separate set of XBees operate on any other frequency band, there are no restrictions on configuration.

148. **Question:** For the virtual track tunnel circuit, can an assumption be made that the tunnel entrance is in a fixed position w.r.t the artifact origin, or will it be necessary to use sensor information to detect the tunnel entrance?

    Answer: With the latest tunnel_circuit code and Docker image, teams can now use the /subt/pose_from_artifact_origin service in the staging area to get the robot location relative to the tunnel entrance. This will allow the robot(s) to enter the tunnel at the start on the competition faster. This document has a short example and this video shows the example running.

149. **Question:** I would like to purchase an e-stop transmitter. I received e-stop receivers today, but no transmitter was included. I assume we are expected to build one using the e-stop transmitter v1 design files in order to test the e-stop receiver. Have any of the other teams built their own estop transmitter? Would you be willing to build another? I would be willing to pay $350 plus shipping for a transmitter.

    Answer: Teams may build their own E-Stop transmitter using the design files, OR they may quickly assemble and configure a "pseudo" E-Stop transmitter for testing their receivers. A pseudo E-Stop transmitter only needs an XBee Pro 900HP radio, an XBee USB Adapter Board, a USB cable, and a computer running Digi's XCTU software. The pseudo transmitter can be configured and operated using the instructions in Section 4 and 4.1 of the README included in the design files. Teams may find the configuration files as well as an updated README in the Transmitter Design Files repository on the SubT Challenge Bitbucket.

150. **Question:** Should we account for the possibility of very deep water passages where we could drown the robot? I.e. should we expect water of depth 5cm and more? Or is it safe to let the robots go inside without water level sensors?

    Answer: The Tunnel Circuit Environment Preview video provides a representative, though incomplete, preview of what to expect at the Tunnel Circuit courses. Terrain elements are expected to vary from event to event, but shallow standing water is within scope. It is not expected that robots will be submerged, but the impact of standing water is dependent on factors including ground clearance, sensor placement, and environmental protection.

7. Questions Answered as of November 13, 2019

151. **Question:** We got information that the awards and winners of the Virtual Competition Tunnel Circuit will be announced on October 30th. Will there be an awards ceremony? If yes, where will it take place?

Answer: We do plan to hold an award ceremony for the Virtual Competition Tunnel Circuit on October 30, 2019. The ceremony will be held virtually and will not require teams to travel for in-person attendance.

152. **Question:** In a competition event, can a team use data that was collected during the first run to label and train new classification models for a future run?
Answer: No, this would be considered using prior knowledge as outlined in Section 9.1.6. of the *Competition Rules Document*. Teams may use data from prior events after the event has concluded, but may not use data from prior runs within the same event.

153. **Question:** Can the Pit Crew personnel use wireless communications with the systems *during the setup time* before an official run begins? Can the Pit Crew personnel use wireless communications *during the run* to initialize, arm, or support launch operations?
Answer: There are no restrictions on wireless communications during the setup time.

    Once the run begins, Pit Crew personnel are only permitted to use wired connections to interface with the systems that are inside the Staging Area. Once a system has crossed the front face of the Starting Gate, Pit Crew personnel may not send or receive data from the deployed systems, whether wired or wireless.

    With the exception of the Safety Officers, only the Human Supervisor is permitted to use wireless communications with the systems during the run. Safety Officers may only use wireless communications for emergency stop transmitters and limited system initialization (e.g., arming, initial takeoff).

154. **Question:** For the Tunnel Circuit Event, is the Team System Checkout intended to evaluate the readiness of the overall team, platforms of a given "type", or each individual robot? If a robot does not initially pass the system checkout, can it be resubmitted for consideration at a later time?
Answer: The Team System Checkout is intended to evaluate both the overall team readiness as well as each of robots individually. Team readiness is evaluated based, in part, on the ability to successfully integrate with the DARPA scoring infrastructure, submit artifact and map reports, and demonstrate safety procedures in line with the rules and guidelines of the event.

    Individual platforms will also be inspected for readiness and safety. All eligible platforms must be listed on the team's robot roster at Team System Checkout. Each of the platform types on a team's official roster must have been successfully qualified before the deadline for each event as described in the *Qualification Guide* document. Each individual platform must pass the Team System Checkout before being permitted to participate in any runs.

    Platforms that do not successfully pass the Team System Checkout may be resubmitted for consideration during the "Working Day" on Monday, August 19, 2019.

155. Question: Are there any limitations on whether a deployed system can be tethered for power, communications, or physical retrieval?
Answer: There are currently no limitations placed on tethers in the rules. However teams are encouraged to consider the significant limitations imposed by the large-scale, potentially dynamic, and complex environments of interest.

156. Question: Do you have an estimate of when the .las data will be posted from the tunnel scan? "This repo provides an initial release of the surveyed point cloud data collected at the NIOSH mine. We expect additional releases in the next couple weeks including higher resolution and LAS versions of the scans."
Answer: High resolution and medium resolution versions of the NIOSH point cloud data are now available and can be downloaded from the links below.

- (20 GB) https://subt-data.s3.amazonaws.com/tunnel_scans/Tunnel_Circuit_FullRes_Scan_EX_Frame.las
- (10 GB) https://subt-data.s3.amazonaws.com/tunnel_scans/Tunnel_Circuit_MediumRes_Scan_EX_Frame.las

Flythrough videos of this data are available at:
- Experimental Course: https://youtu.be/VY4brRg3ifs
- Safety Research Course: https://youtu.be/-qqD243S6RM

Please see the previous announcement and subt_tunnel_scan repository for additional information and resources:
- https://bitbucket.org/subtchallenge/subt_tunnel_scan/src/master/
- Initial Ground Truth Data from Tunnel Circuit

157. Question: When is the new deadline for qualification for the Urban Circuit?
Answer: An updated Qualification Guide is coming soon, but we wanted to provide an update on the expected qualification deadlines for the upcoming Urban Circuit:

- Systems Team Qualification: December 3, 2019
- Virtual Team Qualification: January 3, 2020

New teams that are interested in participating in the SubT Challenge must first complete their Team Registration before submitting qualification materials:
https://www.subtchallenge.com/register.aspx

DARPA may consider qualification waivers for teams that have successfully participated in a prior event. Tunnel Circuit teams will be contacted directly regarding their qualification waiver status.

158. Question: Are you going to guarantee stable (not changing) environments for at least two weeks before the final submission and the same used for the final evaluation? By "environment" I mean CloudSim & Bridge release and choice of AWS machines.
Answer: One of the key lessons learned is the value of stability in the development and competition environments. For the Virtual Urban and Cave Circuit events we intend to continue to use the Ignition Blueprint release of the SubT Virtual Testbed, and implement key code-freeze dates that will ensure that all teams are competing with a stable development and competition environment.

159. Question: Is there a plan to start numbering of CloudSim releases? It would be nice to see in the solution Docker what version was used for AWS simulation. Even better would be "staging releases" where competitors could choose what release they want to use for simulation test (stable or beta version) or run both as "regression test".
Answer: Thank you for the suggestion. We can take that into consideration and will look into how we can facilitate that.

160. Question: Do you plan "transparent evaluation" when everybody could see intermediate results of currently running simulations including competitors? It would be also nice to see YouTube streaming of Ignition simulations.
Answer: We do intend to share the results of all the competition runs. In addition to the logs being provided to each and every one of the competitors for the solutions that you submitted, we will be releasing video footage of your individual runs as well. We encourage you to share those and investigate additional lessons learned that you extract from those videos.

161. Question: Will it be possible for the final undisclosed tunnel environment(s) to be made available to competitors now that evaluation is complete?
Answer: We will be releasing the five new Tunnel Circuit worlds that were used during the competition to the SubT Tech Repo. These are additional worlds that you can use to further test and explore the capabilities of your robot teams. We encourage you to make use of those resources to further enhance your testing, development, and additional technology innovations.

162. Question: Can you describe the scoring details for the Virtual Tunnel Circuit? How many tunnels were used, and how many runs per tunnel? Were tunnels hand-generated or auto-generated? If hand-generated, what range of challenges were designed/invoked to test the competitor solutions?
Answer: There are five competition worlds that were hidden. We conducted three runs for each of those worlds and applied your submitted competition solution to those fifteen different runs. We recently posted the leaderboard on the SubT Community Forum so you can see how your competition solutions performed across all 15 runs.

In regards to designing the tunnels, we were looking to understand how different types of scaling, complexity, density, and variables including the placement of rubble affected the solution. All of these were incredibly interesting design variables for us to explore and it emphasizes why the virtual competition is exciting to us as we are able to explore impact of technologies in the simulation environment at a rate and scale that far surpasses what we might be able to do in the Systems competition, while still benefiting from the lessons learned from the Systems competition.

163. **Question:** What are common problems that were observed across solutions presented to the Virtual Tunnel Circuit? Was the bigger problem in achieving points for artifact submissions false positives, misclassifications, or poor position estimates? How many agents did teams lose on average over the runs? What was the most common cause for attrition?

    Answer: We will be providing all the logs from your runs to each of the competitors. We encourage you to conduct your analysis with those logs to understand those common problems and share those insights, perhaps posting the analysis of your performance on the SubT Community Forum. We think the community would benefit from it and perhaps you might find yourself with additional insights and suggestions on where you could enhance your capabilities.

164. **Question:** What changes are planned for the next virtual rounds?

    Answer: Anticipate some changes in our future Virtual Competition Circuit Events. Certainly with our upcoming Urban Circuit event, you'll see a lot more urban feature sets. The Cave Circuit event will have different naturally occurring cave-like structures. Additionally, anticipate the introduction of new platforms and sensor configurations in the SubT Tech Repo so you can augment or substitute members of your robot team to further balance or enhance the capabilities that you have developed. We'll be introducing models from the Systems completion itself, inspired from the Systems competition robots to leverage in your virtual solution. Additional artifacts will also be introduced in the Urban and Cave Circuits.

165. **Question:** I was thinking it would be interesting to compare some of the approaches and lessons learned between systems and virtual track, but I can't seem to find a recording of the systems track awards ceremony & technical interchange meeting on YouTube. I was just curious if there is a reason for that or if it would be possible for that to be publicly available as well?

    Answer: Please see: DARPA Subterranean Challenge Tunnel Circuit Awards Ceremony

166. **Question:** Can the world defined by tunnel_qual_ign.* files in: https://bitbucket.org/osrf/subt/src/tunnel_circuit/subt_ign/worlds/ be used for virtual Urban Circuit Qualification Scenario? Are there any other worlds, which can be used for this purpose?

    Answer: For the Urban Circuit, qualifying teams must successfully complete the Urban qualification scenario. To achieve the minimum score threshold, teams will need to

accurately locate and successfully report at least five of the artifacts within one hour of simulation time. The updated Qualification Guide can be found on the Resources Page (https://www.subtchallenge.com/resources.html). The full Urban Circuit announcement can be found on the DARPA website (https://www.darpa.mil/news-events/2019-11-12).

167. **Question:** Those of us who did not make it to the first qualification round, which of the circuits do we have to select for qualification in the CloudSim portal? When is the exact deadline for the submission? The SubT manual indicates that the qualification submission should be 90 days before the competition
Answer: Please see this announcement regarding Qualification deadlines for Urban Circuit: Urban Circuit Qualification Deadlines.

Qualification for the Virtual Urban Circuit will require submitting a Docker solution against the Urban Circuit Qualification scenario through the SubT Tech Repo (https://subtchallenge.world/compete). In order to qualify, a team will need to submit a Docker solution that is able to successfully report at least five of the artifacts within one hour of simulation time. Teams may submit against the Urban Qualification scenario as many times as they choose until the deadline for the Virtual Urban Circuit qualification, January 3, 2020 AoE.

DARPA may consider qualification waivers for teams that have successfully participated in a prior event. Tunnel Circuit teams will be contacted directly regarding their qualification waiver status.

8. Questions Answered as of January 30, 2020

168. **Question:** Do you have some recommended setup that you have been building and testing with for the gas release mechanism? Is the gas being released constantly or only once the robot gets close?

Also, how will the room/door be setup? Is the localization point door a closed or open door? If it's open, does that mean we should assume CO_2 will spread to other locations but have less than 2000ppm concentration?
Answer: We do not have a recommended setup for the gas artifact testing but teams are welcome to share their setups with other teams in the Community Resources category on the SubT Community Forum. Make sure appropriate safety precautions are taken including any safety requirements at your organizations. The gas may be either released constantly or remotely activated as appropriate based on location within the course. The CO_2 will be released in such a way as to maintain (or exceed) a concentration of approximately 2000 parts per million (ppm). Based on testing, this threshold is readily and consistently detected by the SCD30 sensor.

The door or passageway to the room will be open. Some CO2 can spread to other locations but the concentration drops off rapidly. The CO2 will be released to maintain a concentration of approximately 2000 parts per million (ppm) inside the room. It may be necessary to enter the room to sense the highest concentration levels.

169. **Question:** After watching the Urban circuit preview I was wondering whether you could provide any guidance regarding the width of doorways - since they seemed to occur in the environment and are often less than 1 meter wide. Also I was wondering whether stairway navigation would be required to reach all of the environment.
Answer: The width of passages at the Urban Circuit site vary greatly and include large open areas as well as narrow constrained passages common in urban environments (i.e., doorways). It is expected that some portions of the course will only be accessible via passages that are approximately one meter in height and/or one meter in width. For the Urban Circuit, it is expected that up to 50% of the competition course could be inaccessible for systems that cannot traverse these passages.

While a majority of passages at the Urban Circuit site are greater than 1 m x 1 m, some passages are as narrow as 0.8 m and a limited number of passages are as narrow as 0.7 m. Some artifacts (up to 10%) may be inaccessible without traversing the more constrained passages.

Stairs are expected to be a challenge element on both competition courses. The height difference between levels requires teams to traverse multiple flights of stairs to reach a different level. One or both of the courses may have additional vertical shafts that could provide access options for aerial, hybrid, or very robust ground robots.

170. **Question:** Are you heating the vent with hot air? Is that air always on? Or is the vent itself heated and there will be no air? Do you have some recommended heating setup?
Answer: The vent artifact will be actively heated with heating elements to present a distinct thermal signature that is at least 30°C above ambient. No forced airflow is being used. No additional details for the heating setup are being provided at this time.

171. **Question:** How should the Tier 2 wireless e-stop be demonstrated for Systems Competition qualification? Do teams wishing to qualify need to obtain the exact DARPA-defined hardware as described in the Transponder and Emergency Stop Integration Guide, or do they just need to demonstrate that platforms can meet the receiver integration guidelines (mounting, power, DIO1 monitoring)? If the latter, what's an example of how that could be done?
Answer: Teams must integrate a DARPA-defined emergency stop receiver on all mobile platforms weighing more than 0.5 kg. The module specifications and configuration guidelines for the Tier 2 E-Stop are detailed in the Transponder and Emergency Stop Integration Guide. Teams must use the specified XBee receiver, but may use any mounting or carrier board options of their choice.

The demonstration videos should include a demonstration of the successful integration of the Tier 2 E-Stop on at least one platform of each platform type. While only one platform of each type is required to demonstrate the e-stop task for platform qualification, all platforms at the competition events will be required to demonstrate the Tier 2 e-stop before being permitted to participate.

172. **Question:** The Transponder and Emergency Stop Integration Guide states that the Tier 2 E-Stop is "DARPA defined and provided" whereas the Qualification guide just says DARPA-defined.

    Is there a means for obtaining the Tier 2 E-Stop system from DARPA? I think that the Guide technically includes enough information in the appendices to recreate the system on self-obtained hardware for qualification purposes, but that section is prefaced with a note that it is provided for team awareness, so I'm a bit confused by the whole thing.
    Answer: DARPA does plan to provide up to ten XBee receivers to teams that successfully qualify to reduce the burden of integrating the DARPA-defined Tier 2 E-Stop. However, qualifying teams are responsible for purchasing and configuring an initial XBee for qualification purposes. In lieu of having an XBee available, teams can meet the Tier 2 E-Stop qualification requirement by demonstrating that platforms can meet the receiver integration guidelines (i.e., mounting, power, DIO1 monitoring). The demonstration video can show the mounting location, demonstrate that appropriate power is being provided with a multimeter, and demonstrate that the platform enters the appropriate e-stop state upon the DIO1 pin being set high. Teams may have varying approaches to set the DIO1 pin to high.

173. **Question:** We are planning to add pull requests for new robot configurations for the urban circuit. We could not yet finish them. Until when do we have to raise these pull requests that shall be available in the urban circuit?
    Answer: The submission deadline for sensor configuration pull requests is December 11. Additional details were sent in an email announcement to registered teams. Teams that have not yet registered may do so at [SubT Challenge Team Registration](#).

174. **Question:** Which android app are you using for the cellphone artifact to keep it discoverable and the hotspot available?
    Answer: A variety of apps are available on the Google Play Store that teams may use for testing that provide these capabilities for a specified interval of time. No additional details are being provided at this time and the specific app may be subject to change across events.

175. **Question:** The "Teams that received Team Qualification waivers must still submit a letter of intent (LOI) to participate by the Team Qualification deadlines." What has to be the content of this LOI? Is there a template for it?

Answer: From Section 2.3 of the [Qualification Guide](#), the LOI should include an updated narrative description including any significant changes to the technical approach, description of any new platforms, and updates to the team roster and/or points-of-contact information. All submissions should be sent as a Word document or PDF to the SubT Challenge email address (SubTChallenge@darpa.mil). No template is provided; teams may use the same format that was used in their original Team Qualification submission.

A LOI is required for teams participating in both the Virtual Competition and the Systems Competition. Virtual Competition teams would include updated team information and an updated technical approach section as outlined in Section 5 of the SubT Qualification Guide.

The deadline for Team Qualifications or Letters of Intent for the Virtual Competition was January 3, 2020.

176. **Question:** In the Announcement for the new configurations there is the statement: "Teams must submit configurations composed of only models and sensors (including sensor range/resolution parameters) currently available on the SubT Tech Repo as listed on the SubT API Wiki." So, we would like to get a principle OK to our plans for new configurations:
    - Teambase: We want to create a Robot model, that will not move. No wheels, no rotors, no IMU. Only the communication module is needed to communicate with the robots and the Base Station.
    - The light cone for the X2 Config 5 robot does not light the complete view of the cameras. So we would like to either change the light cone or add a new configuration with extended light cone for the X4 robot.
    - Adding an additional configuration with a wider camera and light cone angle based on X2 config 5.

    Are these configurations possible by still fulfilling the rules?

    Answer: You are encouraged to submit the pull requests for all of the configurations listed even though they contain alterations to robot models and sensor parameters. However, the pull requests may not be accepted in time for the Urban Circuit in anticipation of the Code Freeze deadline on 18DEC, as configuration submissions that utilize existing models (without parameter changes) are being prioritized. The deadline for new sensor configurations is 11DEC as described in this announcement: [New Sensor Configurations and Upcoming Deadlines for Virtual Urban Circuit](#).

177. **Question:** On Wi-Fi AP for phone artifact you are setting up the SSID with "PhoneArtifactXX" with two random digits. Will there be any specific name for the Discoverable Phone on the Bluetooth? Eventually will it be relatable to Wi-Fi name? Is it known what channel the Wi-Fi will be broadcasting on (i.e., what 20MHz-wide band around the 2.4GHz range)?

    Answer: Each phone artifact will be assigned a unique name in the form of 'PhoneArtifactXX', where XX will be a random, but static, combination of 2 characters that

may be letters and/or numbers. For the Urban Circuit, the phone artifact's unique name is expected to be reflected in both the SSID and the Bluetooth Device Name.

Neither the Wi-Fi channel nor its specific frequency band is being specified. The 2.4GHz Wi-Fi radio may operate at any channel, may vary by artifact, and may change throughout the event.

178. **Question:** Our experience from the Tunnel Circuit taught us a few things about how well different vehicle configurations work for completing the SubT test objectives (identifying artifacts, localizing them, and navigating the courses). I wanted to start a discussion while there is still a chance to add new vehicle configurations before the Urban Circuit code freeze. Here are my thoughts (I hope other teams will chime in if they agree or disagree with what I say here).

    First, for navigation, we learned that the 2D LIDAR on the ground vehicles was aimed too high above the ground to observe shallow obstacles close to the ground. This made us change our ground vehicles to use the 3D LIDAR systems so that we could at least observe the ground and shallow objects near the ground. The ground vehicles with 3D LIDARs are expensive and therefore not ideal, but we resorted to use them because the other ones would almost always get stuck on unobservable objects. So, to address this, we'd like a vehicle that has a 2D LIDAR that works on the full 360 view and is level with the vehicle (like the one now, except full 360), and a 2D LIDAR that is angled toward the ground that can observe the shallow ground obstacles. We will try to add such a vehicle and submit for your review through the new vehicle submission process. I think teams will like having such a vehicle because it should be a lower cost option with close to the same capability as the 3D LIDAR vehicles.

    Second, air vehicles lacked some of the sensing that we desired. We have submitted two new vehicles based on the X4 with the following sensor configurations:

    X4 Vehicle Sensor Config 6: Has the RGBD camera and a 2D 360-degree scanning LIDAR. Also, we added a downward and upward facing point LIDAR based on the LIDAR lite.
    X4 Vehicle Sensor Config 8: Has a 3D LIDAR (same as the X1 vehicle), and also a downward and upward point LIDAR (like config 6).

    We are also planning to submit a vehicle with a ring of RGBD cameras instead of the 3D LIDAR. I believe there is a vehicle being submitted by another team with a similar ring of RGBD cameras on a ground vehicle. These additional vehicle configurations are targeted at having options which can observe objects and surroundings in a 360-degree orientation based on our experience with SLAM approaches which generally rely on 360-degree (or close to 360-degree) scan matching. We have experimented with using SLAM based on smaller fields of view (like just the RGBD camera's 60-degree FOV), and all algorithms we

have tried have failed to perform loop closure, resulting in localization estimates that drift too much and make our artifact geolocations too inaccurate to score.

Third, we cannot observe the ceiling very well with any sensors on the vehicles currently. It may be argued that the cameras can see the ceiling, but generally the camera's forward angle produces a poor view of the ceiling. In the urban circuit artifacts spec, we are told that there will be vents in the environments and that they are ceiling vents. Since we can barely observe the ceiling, we need some vehicle modifications in order to view the ceiling. I think the best way to accomplish this would be a pan-tilt camera capability. Unfortunately, we are not expert enough in ignition sensor modeling to add a pan-tilt camera between now and the Dec. 11 deadline. So, we plan to put an upward facing camera on our new X1 vehicle configurations. We have submitted a request to OSRF to make a pan-tilt camera (or at least a tilt) gimbal for cameras available, but I haven't seen any activity on that in a long time. The OSRF forum post is found here (there are about 5 issues which are duplicates of this one): https://bitbucket.org/osrf/subt/issues/45/gimbal-not-working

Fourth, will there be a thermal camera capability on any of the vehicle configurations available for urban circuit? Such a sensor has not been modeled to my knowledge in the SubT Simulator. Is that something that's being worked on? There are some nice low-cost thermal cameras (generally low res) available now that would be great to have as models in the simulator. As it stands, we plan to only find the vent visually.

Fifth, we would like to have an option to use a more accurate (i.e., less-biased) IMU on the vehicles. We have done some evaluation of different IMU configurations and have found that the bias mean specified in the IMU model has a major effect on VIO and SLAM algorithms. We have found that we need to reduce the bias mean on the accelerometer from 0.1 to 0.01 m/s^2 and the accelerometer standard deviation of 0.009 instead of 0.01 was also helpful. The existing IMU appears to be modeled off of a lower cost MEMS IMU, which is fine for some things, but we would like to have the option to select a tactical grade (or similar) IMU with at least the above characteristics. If using the tactical grade IMU cost more, that would be fine with us. We would select to use that IMU in cases where we need it and suffer the additional "cost". Right now, no option exists. I posted a similar comment on the OSRF forum here and haven't heard anything yet: https://bitbucket.org/osrf/subt/issues/46/imu-details

Last, will a sensor be modeled that can locate phones based on Wi-Fi or Bluetooth like in the systems track?

Sorry this turned into such a novel of a post. This was motivated in large part by the looming deadline to submit vehicles for urban circuit which snuck up on us. I mostly wanted to communicate the reasoning behind the models we're making and see if DARPA concurs with the need for most or all of these changes. Maybe not all of them can be implemented

for urban circuit, but hopefully we can see an influx of improved sensors and configurations in the near future.

Also, I applaud those who have also submitted candidate configurations like SophEng and OSRF. The modifications to light placement, addition of stair detecting sensors, etc. look like they'll be very helpful.

Answer: We appreciate your feedback and are glad to see that the window for sensor configuration submissions is being utilized. Before responding to the six questions below, we want to highlight that the focus of the Virtual Track is primarily to foster development of software-driven innovations in the areas of autonomy and perception. In some cases, limited availability of platforms, sensors, and configurations are intended to focus the kind of software and algorithms that DARPA is interested in exploring (e.g., exploration using limited FOV sensors).

While platform and sensor design are not a major focus of the Virtual Competition, we still welcome your inputs on sensor and platform configurations that will expand the capabilities of your algorithms while also exploring the capability trade space represented in the SubT Virtual Testbed. As you have done in this post, we encourage teams to articulate a justification for the requested submissions and the innovations that they will enable. Submissions will be prioritized to align with DARPA's mission of advancing software-based innovations in autonomy and perception.

As various teams post pull requests, competitors are encouraged to "like" and/or "+1" comments to provide additional community-driven inputs for the model library.

1-3) As described in the "new models and Configs" response, you are encouraged to submit pull requests for your suggested configurations, even those with alterations to sensor parameters. Please note that configuration submissions without parameter changes are being prioritized for Urban Circuit inclusion before the code freeze on 18 DEC.

4, 6) Additional sensing modalities are being planned for future events, but are not expected to be completed before the code freeze for the Urban Circuit. Thank you for noting your interests in these modalities.

5) Altered IMU characteristics may be considered if the proposed characteristics can be supported by a datasheet for a commercially-available IMU. Please include a reference for the cost of the IMU. The SubT Credits assigned to configurations using any new sensor models will, in part, be based on costs of a relevant commercially-available IMU.

179. **Question:** Follow up to question 178. On the IMU question, I just posted a list of IMUs that we're interested in modeling: https://bitbucket.org/osrf/subt/issues/46/imu-details. The prices for these range from $650 to $1800. If these were available along with the existing

model, that would give us a better capability to compare algorithms. I don't know what the existing IMU model was based on or its associated price, but that would be great to know.
Answer: The current IMU model was originally based on the IMU used in the Atlas robot for the DARPA Robotics Challenge. It is not expected that new IMU models will be incorporated in the Urban Circuit, but requests will be considered for later events. New IMU parameters are expected to be added as new sensor configurations (rather than edits to existing configurations) to provide backwards compatibility.

180. **Question:** In light of simulation infrastructure issues which have impacted development like the following: https://bitbucket.org/osrf/subt/issues/307/unstable-rotor-control which makes vehicle behavior different depending on machine loading (which we can't control on the cloud, but is also tricky running locally).
https://bitbucket.org/osrf/subt/issues/261/cloudsim-stops-sending-some-topics
Communication issues between the sim and competitor images, just patched on 12-17-2019.

Is there a chance of an extension on the urban qualification date?

Right now the highest score on the qualifier leader board is still 0, and the highest score on any track is 2 points on urban practice 1. It does seem like the bar being set at 5 is also higher than it needs to be (and likely higher than many tunnel-qualified teams could hit). Is there any chance of that being lowered to 1 or 2 points, just to show that our system has all the pieces needed to compete?
Answer: The Virtual Urban Circuit qualification deadline and threshold will remain as outlined in the SubT Qualification Guide. We understand the challenges of autonomous navigation and artifact detection in these environments are difficult and require significant development time. You are encouraged to continue developing and submitting your solution to the Urban Qualification world and note there are more opportunities to compete in the Cave Circuit and the Final Event.

181. **Question:** Is the Pit Crew allowed in the designated Base Station area before the run starts?
Answer: Yes, the designated Base Station area is open to all team members during the setup time and is only restricted during the scored run.

182. **Question:** Can you confirm that there will be a "Watch Your Step" sticker at all the staircases?
Answer: "Watch Your Step" stickers will be placed on each floor for all staircases that are in play and provide access between levels. The intermediate landings will not include stickers. There may be additional staircases to mezzanine levels, ladders, or curbs that will not have "Watch Your Step" stickers.

183. **Question:** For the vertical shafts, will the safety barriers protect robots from falling through?

Answer: All of the safety barriers include a "toe board" which would prevent inadvertent access for most ground robots.

184. **Question:** Is every such vent in the environment going to be heated and be an artifact? I want to make sure that on the course there won't be a non-artifact non-heated vent that matches the model in the specification?
Answer: Additional vents are present within the course environments; however, they are of different sizes and/or types from the Vent artifact. All of the Vent artifacts are expected to be actively heated.

185. **Question:** I'm experimenting with modified configurations of existing robots, by removing, adding and repositioning sensors. Is there a way to calculate resultant "cost" (as listed here https://bitbucket.org/osrf/subt/wiki/robots)? It would help to have component costs for bare platforms and each sensor.
Answer: You are welcome and encouraged to submit pull requests for new configurations to the SubT Virtual Testbed. The model's SubT Credit value will be assigned by DARPA once the PR is approved. SubT Credit values are calculated based on multiple factors, including but not limited to the price of commercially available components, and may change between events. As such, component credit values will not be released at this time.

186. **Question:** It is clear that we cannot train a model using data from previous runs. Is it OK to change thresholds or adapt what the robot reports based on previous runs? For example, we can currently send the robot a confidence threshold (or distance in metric space etc.) to only report above a threshold. If we are getting too many false positives (an issue we had in the tunnel event), we intend to change this threshold. Do we need to reset this threshold between runs, can we send the same threshold/config again? No back propagation (i.e., modification of the model) is occurring.
Answer: Thanks to the teams who have asked clarifying questions on the topic of prior knowledge and use of data from prior runs. As mentioned in Section 9.1.6 of the Competition Rules Urban Circuit document, an exact enforcement of the prior knowledge prohibition can be difficult and in some cases site-dependent. In particular, the desire to permit multiple runs on the same course introduces some difficulty in defining permitted use of prior run data. We expect to further update this section in the rules for future events, but will offer the below guidelines to provide additional clarity for the Urban Circuit.

Possible use of data from previous runs may be permitted on a case-by-case basis for the Urban Circuit and must be in the spirit of the competition to develop technologies for exploring unknown subterranean environments.

Use of prior run data is **less likely** to be permitted if it would improve system performance on a **specific course**. Use of prior run data is **more likely** to be permitted if it would improve system performance on **any generic third course**.

Use of prior run data is **less likely** to be permitted if it requires significant off-board processing or curation **after the run**. Use of prior run data is **more likely** to be permitted if it could have reasonably been performed by the Human Supervisor or Pit Crew **during the run**.

The decision regarding use of prior run data to train new classification models stands as written in the rules document. Regarding the use of prior run data to adjust confidence thresholds, this use is permitted because it is not considered to be overly course-specific and could reasonably be performed by the Human Supervisor during the run.

9. Questions Answered as of April 21, 2020

187. **Question:** Is there a plan to share the team map output data available to DARPA via "Mapping Interaction Protocol" also to the team "Pit Crew"? The map data are optional (at least not sponsored teams) and this would be a good motivation to publish them (the team typically does not know much what is going on). In real world scenarios the map would be probably available while the number of operators would still be limited.

   Another possibility would be to delay display of status by say 10 or 15 minutes, if real time would be a problem?

   Note, that our ultimate goal is to have "operator-less" operation similar to the Virtual Track, and this could make the competition more interesting for the non-operator members of the team.
   Answer: Thanks for the question and suggestions. There are some operational scenarios of interest in which the Human Supervisor may be remotely located from the Pit Crew. The intended role of the Pit Crew in the SubT Challenge is limited to supporting the deployment of the systems into the course. Pit Crew personnel are prohibited from viewing or accessing information related to mapping and/or artifacts because it is considered Course Data. Team personnel roles and restrictions on data access may be adjusted for future events.

188. **Question:** Are there any guidelines or restrictions detailing what teams can/cannot post to social media during the Urban Circuit event?
   Answer: We encourage you to share your stories directly via your social channels, website and local media, and to engage with DARPA on social media using #SubTChallenge. For the sake of fairness, we ask that you refrain from sharing competition-specific information until all scored runs are completed.

189. **Question:** Is it possible to have two Cell Phone artifacts with the same ID?
   Answer: The Cell Phone IDs are unique. For the Urban Circuit event, Cell Phone artifacts are retrieved and reinstalled for each run day, so the location of a specific Cell Phone artifact may vary between days.

190. **Question:** Is there a deadline for new configuration submissions for Virtual Cave Circuit?
Answer: We are not expecting to provide a sensor configuration submission window for Cave Circuit. The focus of feature additions to the SubT Virtual Testbed are expected to be new robot models. Teams are welcome and encouraged to submit robot models through the Virtual Model RFI which closes March 31, 2020.

191. **Question:** We would like to be able to access scoring data from previous runs on the virtual circuit. The best case scenario would be processing 3 x number_of_worlds runs sequentially and to have previous runs scoring readable by the current run. The data would include (for each run): world number and the score. If this is not acceptable, only the scores would work too.

    This data could be used to choose between different strategies (in lieu of a random number generator) and detect a complete failure (zero score) due to unpredictable timing or latency issues.
    Answer: Teams are provided log and score data from all their runs at the completion of the Circuit Event. If the question is asking whether a CloudSim instance can read the score of a previous CloudSim run, there is no plan to incorporate this feature. We encourage teams to test their solutions using the Simple Worlds and Practice Worlds to evaluate different strategies and troubleshoot potential issues.

10.   Questions Answered as of July 6, 2020

192. **Question:** During the Urban Circuit we were asked to send point cloud diffs instead of the full point cloud every transmission. Is there a common way of doing this? We use Octomaps and then convert them to point cloud for DARPA, but it's the entire point cloud every iteration. I haven't seen a method of sending just point cloud diffs, but I feel like I'm missing something obvious.
Answer: When sending point clouds to the mapping server, you are encouraged but not required to send map "updates" instead of sending the complete map for every iteration. As stated in the Urban Circuit ICD, the available network bandwidth for scoring and mapping updates is 100Mbps. You should not need to downsample or send only "updates" unless you expect to exceed this bandwidth. With that said, you may still choose to send only map updates for efficiency. We are not immediately aware of open-source tools to extract the "diff" between consecutive maps, but maybe other teams would be willing to chime in with their approaches.

193. **Question:** Would it be possible to receive SSID and Bluetooth names for each of the "Cell Phone" artifacts?
Answer: The Cell Phone IDs are not mapped to a specific artifact location. For the Urban Circuit event, Cell Phone artifacts were retrieved and reinstalled for each run day, so the

location of a specific Cell Phone artifact may have varied between days. See also: Question #189 Cell Phone IDs for Urban Circuit.

194. **Question:** The new falling rocks feature will be triggered by presence of the robot in certain volume. Can the rock fall occur into that volume and potentially damage or destroy the robot? Can a robot trigger a rock fall into the volume occupied by another robot
Answer: It is possible for the rock fall to occur while there are robots within the fall zone. The trigger and rock placement are expected to be selected such that rock falls are not likely to fall on the robot which activated the trigger. However, it is possible for a robot to trigger a rock fall while there are other robots occupying the fall zone. Vehicle damage is not expected to be modeled for Cave Circuit. However, a robot may be indirectly disabled (e.g., knocked on its side/back) or have its path blocked.

11. Questions Answered as of December 8, 2020

195. **Question:** Is it possible to register for the Cave circuit and Final Event without having participated in the previous events i.e. Tunnel Circuit and Urban Circuit? Is there a team size limit? What's the deadline for the Cave Circuit registration? We could not find the Cave Circuit rules document on the Resources Page? Has it been released yet?
Answer: It is still possible to register for the Cave Circuit or Finals. It is not required that teams have competed in previous events. There is not a limit to team size, although there may be a limit to the number of people that can come to the competition site based on venue restrictions. The deadline is still to be announced. We have announced that the Cave Circuit will be no earlier than October due to a schedule shift due to COVID-19. The Cave Circuit rules document has not been released yet. It is anticipated that it will be released closer to the event, approximately three months in advance. The rules from the Urban Circuit are available and would be a good starting point.

196. **Question:** Do we need to specify the final team configuration in advance (e.g. as a part of the qualification process) or could we decide it just before the final submission?
Answer: The team configuration used for the Cave Circuit qualification does not have to be the same team configuration used in the final competition submission. You may update your team configuration and solution up until the submission deadline. The qualification narrative should reflect your plans for the final submission. If your approach changes significantly during practice, you are encouraged to update your team's narrative in the SubT Challenge Team Portal.

197. **Question:** Is it possible to participate in the SubT Virtual Competition with two different configurations? For example, could we create two teams Solution1 and Solution2? Are there any restrictions on people or code exclusivity among participating teams?
Answer: Each team is only permitted to submit one final submission to be scored. Different teams must be traceably separate and distinct in personnel, approach, and code. In many

cases, publicly released (open source) software may be reasonably used across multiple teams. The qualification narrative should address any actual or perceived overlap in personnel or software with another team.

198. Question: Will there be an integration event in 2021 before the finals?
Answer: We are considering options for an integration event similar to the SubT Integration Exercise (STIX) that was held in advance of the Circuits Stage. Such an event would be optional as a way for teams to gain access to representative testing environments and confirm integration with the DARPA instrumentation and scoring systems.

199. Question: Is there funding available that our Systems Competition team can apply for?
Answer: We do not expect to open a public call for proposals or funding for the Finals Stage. Funding decisions for the Finals Stage are based on performance during the Circuits Stage.

200. Question: Can the Systems Competition Cave Circuit prizes be moved to the Systems Competition Final Event (either for self-funded or any teams)?
Answer: No adjustments to the prize structure are being announced at this time, but any changes will be highlighted in future announcements related to the Finals Event.

201. Question: The new rules state: "The Team Configuration is also limited to a maximum of five models of a given type (e.g., five X1 platforms of any payload configuration)." Is MARBLE_QAV500 (Small UAV) considered a different type than EXPLORER_DS1 (Medium UAV) and SSCI_X4 (Large UAV)? Since there is no specific Xn (X5?) category for medium UAVs, I wanted to verify.
Answer: Unique robot types are defined by the base platform. You can see a full list of unique robot platforms here. To answer your specific example:
- "MARBLE_QAV500" has base platform QAV500
- "EXPLORER_DS1" has base platform DS1
- "SSCI_X4" has base platform X4

Therefore, these are all considered unique platform types. Here are a few more examples:
- "X4" and "SSCI_X4" have the same base platform type (X4)
- "COSTAR_HUSKY" and "MARBLE_HUSKY" have the same base platform type (HUSKY)

202. Question: Will a cave environment preview be released (or other information to inform cave testing)?
Answer: We expect to release video or other data in Fall of 2020 to help teams prepare for the cave-specific challenges expected at the Finals Event.

203. Question: After the submission window for Cave Circuit ends, will we receive logs from all submissions during the window, or just from the last one?

Answer: Only the final competition submission will be run against the Cave Circuit competition scenarios and scored. You may submit other solutions to the competition worlds after they are released.

204. **Question:** When can we expect release of the competition worlds?
Answer: Competition worlds will be publicly released shortly after the Awards Ceremony for Cave Circuit.

205. **Question:** Will we be able to see the score of the submitted solutions during the submission window?
Answer: No, scores for the competition submissions will only be available after the submission window has closed. Final results will be released during the Cave Circuit Virtual Competition Showcase and Awards, which will be streamed on Nov 17.

206. **Question:** Is there a plan (similar to Urban Circuit) to use one of the practice worlds also as a competition world (with differently distributed artifacts)?
Answer: Yes, one of the three Cave Circuit Practice Worlds will be included as a Cave Circuit Competition World with artifacts relocated. You are encouraged to use the Practice Worlds on Cloudsim to prepare your team!

207. **Question:** We have uploaded our containers to the docker registry, however when I pass the information the system gets stuck at "LaunchingPods". Is there any place where I can clarify what I should input for the docker url?
Answer: There are instructions and an example docker image URL on the Cloudsim Submission wiki page. You may also email subt-help@googlegroups.com for help with Docker repository access and submitting your solution to Cloudsim.

208. **Question:** Is it necessary to qualify for the Cave Circuit in order to be eligible to participate in the Final Event to be conducted in 2021?
Answer: The qualification requirements for each event are considered separately. It is not necessary to qualify for any previous events in order to be eligible for the Final Event. Failing a previous qualification attempt does not preclude a team from resubmitting a revised qualification submission, subject to qualification deadlines for any given event. DARPA may adjust the qualification rules for each event. Qualification requirements for the Final Event will be released at a later date.

209. **Question:** In the rules it mentions: "DARPA intends to fund up to six teams in the Finals Stage out of the teams competing in the Systems and Virtual Competition. Is this still a potential and is there a process?
Answer: As recently announced on Twitter, DARPA has awarded a contract to CTU-CRAS-NORLAB for the Systems Competition. At this time, DARPA is not intending to fund any additional teams for the Finals Stage of the SubT Challenge.

210. **Question:** I can't find the SubT Challenge Guidelines document on the website resources section anymore. Has it been removed? Is it still accessible?
Answer: The SubT Challenge Guidelines document has been superseded by the latest Competition Rules document listed under [Resources](#). Currently, the latest version is the [Cave Circuit Competition Rules](#) document last updated July 30, 2020.

211. **Question:** What format should we expect for the final competition? Will it be essentially 3 separate courses or will it be 1 big course as shown in DARPA concept pictures? How many runs will it be for each? Would it be 2 total runs or 2 per sub-category for 6 total?
Answer: We look forward to releasing additional information related to the Final Event rules and run format approximately nine months before the Final Event.

12. Questions Answered as of April 1, 2021

212. **Question:** How long will Cloudsim logs be retained on S3 bucket?
Answer: All practice and competition logs for Cloudsim runs will be retained on the S3 Bucket until at least 1 month after the Final Event logs are released in Fall 2021.

213. **Question:** If we would like to change/add sensor packages on existing robots, do we need to go through the full simulation model preparation and submission process, or are we able to request additional sensor package configurations (i.e. combinations of existing sensors, not novel sensor development) be added to the repo by OSRF?
Answer: DARPA's emphasis and prioritization is on new robot model submissions. Sensor configuration submissions will only be addressed if extra review time is available and if the submissions are aligned to DARPA's priorities for advancing technology insights. All submissions are expected to follow the process outlined in the Model Preparation Guide.

214. **Question:** Will be the Final Event be three days only? What are the dates the teams should use for travel arrangements?
Answer: The Sept 21-23rd dates as listed in the recent [press release](#) represent the public-facing (e.g., broadcast) competition days for the Final Event. Similar with the Circuit Events, competitor teams will need to be on-site prior to these competition days for activities, such as team orientation and systems checkouts.

The tentative dates for competitor teams to be on-site is September 18-24. These dates are anticipated to be finalized once the number of qualified teams for the Final Event has been set.

215. **Question:** Could you please provide specifications of stairs (step dimensions) and the minimum dimension of the landing area in between flights of stairs? Previously stickers were used to identify stairs. Will those still be there or should we not expect them to be there?

Answer: In the spirit of developing technologies to rapidly and remotely explore unknown subterranean environments, we do not anticipate providing stair specifications, identification markings, or landing area dimensions for the Final Event.

216. **Question:** The Model Submission wiki entry states that new sensor configs of existing robots only need to provide datasheets of the sensors, the URDF/SDF files and so on, but do not need to provide bagfiles of the sensor packs being mounted on the real robot, neither do they need to provide photos of the integrated sensor suite. Is my understanding correct?
Answer: The latest version of the Model Preparation Guide on the Resources page states that photos of the sensor payload onboard the robot may be requested by DARPA. If the payload cannot be shown mounted to the physical robot, DARPA may request relevant information (e.g., weight of the payload and carrying capacity of the robot) until the remaining data can be provided.

Please note that DARPA's emphasis and prioritization is on new robot model submissions for the Final Event, but sensor configurations may be considered in particular when modeling a physical robot's actual payload.

217. **Question:** We plan to use a passive vehicle - a kind of trolley for extending wireless reach. The trolley will be attached behind one of the robots, which will take it about 50-100 meters in the tunnel and then detach it. Since then the trolley should be static. It will have no sensors onboard.
Answer: In your qualification materials, please include any specifications such as cable length, wireless specifications, size, weight, and anything else that could be relevant for safety and/or recovery. Please include details related to the detachment mechanism and which robots are expected to perform the towing. As there are no other sensors onboard, we do not require demonstration videos for the Emergency Stop, Mobility, or Perception tasks for this passive platform.

218. **Question:** The updated rules say we have to make additional e-stop transponders ourselves. There are some support files at:

https://bitbucket.org/subtchallenge/transponder_design/src/master/

but they are more related to the transmitter than to the transponder (i.e. I do not see any code that would handle interrogation by the gates). Should we wait for some building guide to be published?
Answer: E-Stop transponders may be configured using the instructions in Section 2: "XBee Configuration" of the README.md located in the transponder_design repository at:

https://bitbucket.org/subtchallenge/transponder_design/src/master/README.md

These instructions are the same for both the "transmitter" and "transponder" XBees. There is a "NOTE" clause at the bottom of Section 2 indicating how to perform the configuration for the "transponder". The .xpro configuration file for the transponder can be found at:

https://bitbucket.org/subtchallenge/transponder_design/src/master/xbee_profiles/transponder_configuration.xpro

The interrogation of transponders is entirely implemented on the gate; no special code/functionality lives on the transponder besides basic XBee network configuration.

Lastly, DARPA will re-flash each of your transponders during Systems Checkout at the final event to ensure that they are configured properly for the event. You are not required to configure your transponders before the final event unless you want to use them for your own testing.

13. Questions Answered as of July 30, 2021

219. **Question:** Assuming 1 laptop and 1 monitor, we'll be needing to mirror both of our displays via provided HDMI cables back to DARPA. Will these cables be split or do we need to provide the laptop with four HDMI interfaces and/or split them ourselves?

    Except for the plug-in HDMI capture devices, could you also provide pass-through HDMI capture devices? That would be much appreciated, because we plan a 3-4 monitor setup with a single computer and we plainly don't have 8 video outputs.

    What about DisplayPort?

    What is the model of the splitter DARPA will use?
    Answer: DARPA's intent with the HDMI capture is to remain flexible in what we capture and unobtrusive in the way we capture it. All capture devices are expected to be pass-through capable. We will have adapters for DisplayPort and Mini DisplayPort.

    For some use cases, we recognize that capturing both an integrated display and the extended desktop may be problematic for some laptops. In these cases, DARPA understands that not all displays may be externally available.

    We intend to use the URayCoder UHE265-1L or a similar device.
    https://www.amazon.com/dp/B07CP3G86L

220. **Question:** Will DARPA provide STL files for the artefact 10 - Cube or should they be made from the virtual repository model? How fast will the RGB colors change and what type of Bluetooth radio is expected to be used on the Cube artefact?

Answer: DARPA plans to make the design files available soon on the [SubT Bitbucket](#). We also intend to provide information including printer material, LED strips, and LED controller being used. We do not intend to specify the rate of color change. The embedded wireless radio is a Broadcom/Cypress BCM43438 chipset that supports 802.11 b/g/n Wireless LAN and Bluetooth 4.1.

221. **Question:** I was wondering if there are some additional parts that are missing from the files? For example:
    a. The Bluetooth transponder and the code / settings for this device. On another post you mention that is will the Broadcom/Cypress BCM43438.
    b. Is there a part to mount the cube to something? There appears to be an additional 5 holes in the center of the back plate. Did this have an intended piece that bolts on it?

    Possibly also worth mentioning that the Formlabs printer required is either a Form3L or Form 3BL due to the large build volume required.

    Are you able to provide an image of how you assembled the LEDs on the inside of the cube? It is hard to determine the number of LEDs that you have installed.
    Answer: The embedded wireless radio is a Broadcom/Cypress BCM43438 chipset that supports Bluetooth 4.1. The mounting method varies as it is application dependent. Teams may chose a mounting method that works for their application. Teams may use a variety of printers and materials to approximate or match the design of the Cube artifact being used. If a closer match is desired, teams may use Formlabs clear resin on a Formlabs machine with a sufficient build volume.

    Four LED strips containing 6 LED modules each are used to illuminated the Cube artifact. The strips are mounted to 3d-printed (transparent white ABS material) arc-shaped brackets that attach along the edges of an acrylic shelf that fits inside the cube and is held in place by the backplate. Please see the [SubT Bitbucket](#) for recently added CAD assembly file and reference images.

222. **Question:** I see all gas artifacts in virtual worlds have the same dimensions and localization point. Can we count with that also for the finals or is it possible there will be other "shapes" of gas artifacts?
    Answer: The room size and shape of the Gas artifact may vary across courses. The localization point of the gas artifact is the center point of the entry door threshold (at floor level) of the room. Please see the [Artifacts Specification](#) document for additional information.

223. **Question:** Will notifications be sent out (via email) to teams that qualify for the final virtual track event? When should we expect to be notified?
    Answer: Please see Section 6 of the [Qualification Guide](#).

"Submissions will be reviewed for validity and qualifying competitors will be notified within 10 business days after the qualification deadline."

224. **Question:** Could we get the product or purchase link to the register box of artifact Vent used in the Urban event? Thanks!
Answer: The register box is a custom fabrication and not available for purchase. Teams may construct their artifacts using any materials or methods that are readily available. The dimensions of the box (not including diffuser) are 605 mm x 605 mm x 158.75 mm. The artifacts being used at the Final Event are made out of 20-gauge mild steel and painted using Smooth Gray Enamel Primer Spray Paint:
https://www.acehardware.com/departments/paint-and-supplies/spray-paint/hobby/17031

225. **Question:** Can we rely on all staging areas in all finals competition worlds to be the same as the one used in practice worlds? Will its position relative to artifact_origin frame also be always the same?
Answer: The Finals Staging Area and artifact origin location will be consistent across all competition worlds for the Final Event.

226. **Question:** The operations guide indicates that the "Teams will be given 24-hour access to their Team Garage and shared Practice Areas from team move-in on September 19 through move-out on September 24." Will the garages or any similar space be available after the competition, for those staying for the team test days to do further data collection and testing?
Answer: Teams will not have access to their Team Garages or Practice Areas during the post-event Team Testing Days. However, only one team will test on the course at a given time, so the Staging Area and Pit Crew Area will be available for the team's use.

227. **Question:** About the testing after the competition. This is excellent news. Will the DARPA infrastructure, including object, remain? Could we get video and other sensory data? It may help in getting ground truth.
Answer: We do not expect to have the DARPA data collection or scoring infrastructure operational during the team testing period. The Staging Area and course lighting will be powered and the artifacts will be left in their final configuration locations. Where possible, some artifacts are expected to be powered (e.g., Survivor). However, some artifacts may not be powered (e.g., Cell Phone, Cube). DARPA expects to release the ground truth locations of the artifacts at the conclusion of the event, in advance of the team testing period.

228. **Question:** The Operation guide says: "If a Systems Team is also competing in the Virtual Competition, they are limited to a total of twenty (20) members at the Final Event across both competitions."
   a. What is the meaning of the limit for the virtual competition?
   b. Does the limit also apply for the Awards Ceremony?
   c. Does the limit also apply for the Team Test Days after the competition? Can non-registered team members enter the premises for the Team Test Days?

Answer: a. To clarify, the limit on team personnel only applies to on-site attendance for the Final Event. Virtual Teams that make it to the Prize Round will be invited to attend the Final Event in-person for September 23-24, 2021. Systems Teams are limited to twenty (20) members in attendance at the Final Event. Virtual Teams are limited to six (6) members in attendance at the Final Event. If a team is competing in both the Systems Competition and the Virtual Competition, they are still limited to twenty (20) total members in attendance at the Final Event.

b. Yes, the limit also applies for the Awards Ceremony due to COVID-19 social distancing constraints. DARPA will continue to assess the situation and constraints and make adjustments as necessary.

c. Teams are permitted to bring up to 50 personnel for the Team Test Days. Team members that are not participating in the Final Event but are participating in the Team Test Days will be required to enroll via the online enrollment form, but as a separate attendee type. This enrollment information will be distributed to teams at a later date.

229. **Question:** There used to be the 48-hour limit for cloudsim simulations. Looking at github issues, there are lots of teams (including us) whose simulations run for 60+ hours. So how is it with this limit? Will the 48-hour limit be applied in evaluation of the preliminary round?

    I cannot find any real-world time limit in the referenced document. Does it mean there is not real-world time limit for the scored runs?
    Answer: Competition simulations will be terminated in accordance with the run termination conditions specified in the SubT Challenge Competition Rules. The real time limit has been increased to ensure real time duration does not terminate a run prior to these conditions.

    Cloudsim's real time limit is in place as a final stop if an erroneous simulation fails to terminate properly. The real time limit is not enforced as a competition rule. The real time limit is currently set to 96 hours but may be adjusted as necessary to allow simulations to reach one of the documented competition termination conditions.

14. Questions Answered as of November 1, 2021

230. **Question:** During the sequestration period can wireless radios that would normally be on during the competition remain on? Specifically, radios that are used to communicate with the base station or detect artifacts. Do we need to modify our robot designs to enable these to be turned off for the sequestration period?

    Does this include the bluetooth radios that are used solely for artifact detection?
    Answer: No wireless communications are permitted during the sequestration period, including wireless radios that would normally be on during a competition run. If you intend

to interface with your robots during the sequestration period, you will need to disable wireless radios and only use wired connections. You may also chose to keep your robots unpowered during the sequestration period.

Yes, all wireless devices must be disabled or turned off during the sequestration period.

231. **Question:** Are the maps only available if a robot publishes them, and not the Base Station? I added our base station's point cloud to /cloud but I'm not seeing an option to view it.
Answer: The Virtual Mapping Server and SubT Virtual Portal point cloud visualization currently support maps published to the /cloud topic on robot instances but not on team base stations. We will note map support for the Base Station as a feature request. The Mapping Server API contains additional details on currently supported topics.

232. **Question:** At prior circuit events, each team was allotted 30 minutes before officially starting their timed run to (1) move robots and equipment into the staging area, (2) set up their base station, (3) verify communication to the DARPA server (in the first 15 minutes), and (4) configure their robots in the staging area.

Because there is no specification for this listed in the Final Event Rules document, we would like to confirm that teams can expect to have this 30-minute setup window for each Preliminary Run as well as the Scored Run?
Answer: Similar to previous events, teams are expected to have 30 minutes prior to their run for Staging Area setup and network verification. The first 15 minutes will be allocated for communication verification with the DARPA Command Post servers.

Please note that this does not include transport time. Due to the physical separation between the Team Garages and Staging Area, teams are required to be in the Team Garage area at least 90 minutes before their run for E-stop verification and for personnel and equipment transport to the Staging Area.

233. **Question:** We are interested in continuing to run tests in the AWS CloudSim past the Virtual track submission deadline next week. How long will we continue to have access to the testbed in the cloud?
Answer: Teams are expected to have access to practice simulations on Cloudsim until at least November 15, 2021. Further extension of SubT Virtual Portal and Cloudsim access is under consideration by DARPA.

Inputs and/or suggestions for long-term sustainment of these SubT Community capabilities and resources are also welcome.

234. **Question:** Can a Pit Crew member use a cell phone to detect and/or localize RF signals coming from the course? (e.g., Bluetooth from the Cube artifact)

Answer: No – this would be considered accessing course data by a Pit Crew member which is prohibited by Section 8.2.

235. **Question:** A team uses a Total Station in support of calibration tasks within the Staging Area. Can a Pit Crew member interface with the Total Station and then send data from the Total Station to the Base Station via a wired connection?
Answer: Yes – in the described scenario, the Total Station is essentially functioning as a stationary robot and the Pit Crew can interface with it as with any other robot in the Staging Area.

Note that the Total Station is only providing the Pit Crew member access to status data from the Total Station itself and is only collecting exteroceptive data that is being collected from within the Staging Area – consistent with Section 8.2 of the rules document.

However, please note that the communication in this scenario may only be unidirectional from the Total Station to the Base Station. The Base Station may not provide other status data or course data to the Total Station interface.

236. **Question:** If a Pit Crew member has a wired connection to a robot in the Staging Area, can that Pit Crew member access Status Data updates from other robots that are sharing data wirelessly with the robot located in the Staging Area?
Answer: No – the Pit Crew member's limited role is to support operations tasks such as physically deploying robots, performing repairs, modifying software or firmware, and changing batteries.

The described scenario is not permitted because the Pit Crew member is effectively using wireless communications with other robots – a function that is only permitted for the Human Supervisor via the Base Station.

The Pit Crew personnel are only permitted to access status data of the robot they are connected to and working on in support of the operations tasks described above.

Status Data from other robots may only be provided to the Pit Crew personnel via a wired display coming from the Base Station as described in Section 8.2.2.

237. **Question:** Can the Pit Crew check for unexpected wireless networks in the Staging Area as a permitted operations task? (We are concerned that if they inadvertently see wireless signals from the course that this could be considered breaking the rule about Pit Crew personnel not being allowed to access course data.)
Answer: Only the Human Supervisor is permitted to use wireless communications during the run. The Pit Crew is not permitted to use wireless communications during the run with the exception of the Safety Officer for the limited use cases described in Section 8.2.3.

The restriction on wireless communications is not enforced during the setup time before the competition run begins. However, teams should consider their operations during setup to avoid inadvertent access to course data by the Pit Crew personnel.

238. **Question:** Is telemetry data and/or IMU data considered permissible Status Data that can be displayed to the Pit Crew?
Answer: Section 8.2.2 states: "*The Pit Crew is only permitted to view limited system status data such as battery health, network status, and real-time telemetry as long as the data is derived only from proprioceptive sensors.*"

Real-time (i.e., instantaneous) telemetry and IMU data may be displayed to the Pit Crew as long as the data is derived only from proprioceptive sensors. Note that the following would not be permitted:
   - access to visual odometry data (utilizes exteroceptive sensors)
   - access to time-history of telemetry or IMU data (could be used to derive course information)

239. **Question:** Previous discussions on the final event indicated a live-stream of the final runs. With the current schedule and sequestration plans, is it correct to assume there will be no live-stream, and instead, the only broadcast will be 09:30am - 12:45pm local time on Sept 25th? i.e., is the plan that there is no way for anyone to see any footage of the prize round until the morning of the 25th?
Answer: The Broadcast is different than previous events and does not contain full run coverage for all run days. The current Broadcast schedule is as follows:

   - Sept 21, 2021 – 2:00pm - 3:00pm EDT Introduction to the SubT Challenge Finals
   - Sept 22, 2021 – 2:00pm - 4:00pm EDT Virtual Competition Prize Round and Systems Competition Preliminary Round Coverage
   - Sept 23, 2021 – 2:00pm - 4:00pm EDT Virtual Competition Prize Round and Systems Competition Preliminary Round Coverage
   - Sept 24, 2021 – 9:30am - 5:00pm EDT Virtual and Systems Competition Prize Round Coverage, Awards Ceremony, and SubT Summit

240. **Question:** In the updated Operations Guide it mentions that all e-stop tiers will need to be checked out for each robot prior to each run. Doing this for our UAVs takes a large amount of time and introduces possible mistakes (e.g., putting props back on incorrectly). Would it be possible to waive this requirement for the UAVs, or only check out one of the UAVs prior to each run?
Answer: The emergency stop checkout is required before **each** run for **each** individual mobile platform weighing more than 0.5kg. We recognize that certain platforms will be more complex to re-validate or may require time to reset before a run. DARPA staff will coordinate with teams during the initial systems checkout to determine re-validation requirements for each of their platforms and arrange a time to perform the re-validation checks earlier in the

competition day to ensure enough time to reset before being loaded for transport to the Staging Area.

241. **Question:** Cellphone and Cube artifact hardware can broadcast two types of signals - Bluetooth classic, BLE. What type of signal is used in the competition? Is only one signal broadcast, which one? Or both signal types?
Answer: The cell phone is a Samsung Galaxy J8 with Bluetooth 4.2. Bluetooth discovery mode is enabled through the cell phone's native Android 8 Bluetooth interface.

The cube uses a Raspberry Pi Model 3B with a BCM43438 chipset that runs Bluetooth 4.1. Bluetooth discovery mode is enabled with a script that makes calls to bluetoothctl v5.50. The script is below for reference:

```
sudo bluetoothctl <<EOF
power on
discoverable on
pairable on
EOF
```

242. **Question:** Will this be capable of more than 1080p? When we tested it would drop the resolution of our external monitor to 1080p.
Answer: The capture devices only support resolutions up to 1080p. DARPA's intent with the HDMI capture is to remain flexible and unobtrusive. For some use cases, we recognize that capturing the display may not be possible.

243. **Question:** Was the final course areas released via point cloud or another georeferenced format? Much like the early in the process NIOSH mine data?
Answer: A down-sampled point cloud of the Final Event competition course in the local (competition) coordinate frame is available in the SubT Bitbucket repository: https://bitbucket.org/subtchallenge/finals_ground_truth/src. In the near future, we intend to release a higher resolution version, the georeferencing transformation, and aids to visualize the pointcloud using RViz — similar to previous events. These will be announced in this forum as they are available.

244. **Question:** Will this be capable of more than 1080p? When we tested it would drop the resolution of our external monitor to 1080p.
Answer: The capture devices only support resolutions up to 1080p. DARPA's intent with the HDMI capture is to remain flexible and unobtrusive. For some use cases, we recognize that capturing the display may not be possible.

245. **Question:** Can you describe how the map metrics shown in the SubTv mapping segments were calculated?
Answer: The mapping server's real-time analysis was calculated by comparing the submitted map point cloud to the "ground truth" point cloud. The "ground truth" point cloud

was created for both Virtual and Systems courses by uniformly sampling the Virtual course mesh and by scanning the Systems course, respectively. The displayed data points are briefly described here:

- Green "inlier" cloud display — points in the submitted map within 1-meter distance from the closest ground truth point
- Red "outlier" cloud display — points in the submitted map greater than 1-meter distance from the closest ground truth point
- Cloud Size — total number of points in the submitted map, accumulated across multiple clouds when partial maps were sent
- Coverage — percentage of ground truth points within 1-meter distance of a submitted map point, i.e., `<ground truth points within 1-meter of an inlier point> / <total ground truth points>`
- Deviation — percentage of submitted map points greater than 1-meter distance from the nearest ground truth point, i.e., `<outlier points> / <total submitted points>`

The map analysis software for calculating these metrics will be released along with a publication describing the metrics in detail. These resources will be posted in the "Community Resources" category when ready.