Broad Agency Announcement (BAA) Responses to Questions

Smart Electrically Powered and Networked Textile Systems (SMART ePANTS) Program

N66001-22-S-4705

Contents

General Questions

Q1: *Can a (compliant) external partner of the proposer fabricate the sub-assemblies to be assembled in the US for the final deliverables? If so, for site visits, how would our external partner be managed?*

A1: **Proposers may assemble their teams using whatever partners they choose worldwide, provided that they conform to BAA stipulations (no US national laboratories or other federally funded institutions). Participation in site visits by**

teammates is generally expected to be in person, depending on level of participation in the program.

Q2: Should all AST track 1-3 components be launderable? I.e. if there are modular, detachable components to the AST, would this be acceptable?

A2: No detachable AST components are permitted.

Q3: Is the AST form factor design and material choice mainly up to the proposer or are there limitations to the options (other than functional requirement)?

A3: Any proposed solution must conform to BAA requirements for garment type (See Section 1.A.1), and not contain out-of-scope components (See Section 1.C).

Q4: The BAA refers to font name, font size and page margins in reference to a word document application. If we are to submit the proposal in PowerPoint, are there any guidelines for this around the same?

A4: All applications must be readable using common commercially available software, such as Adobe Acrobat, or a Microsoft Office application. All applications must comply with the same font name, font size, and page margins stipulated in the BAA, regardless of the software package used.

Q5: Can a company propose as a subcontractor on multiple proposals?

A5: Yes. Any institution may be included on any number of proposals as a prime or subcontractor. In case of multiple awards, the institution would have to show how they plan to successfully resource all awards. In addition, the institution in question would not be able to charge the Government twice for the same work.

Q6: Would we be able to submit a proposal just to solve the power supply requirements without any of the three sensor tracks?

A6: No. All applications must propose an integrated solution to meet program metrics.

Q7: Are non-US national laboratories allowed to propose to the program?

A7: Yes, non-US national laboratories may apply for funding as long as the laboratory does not receive the majority of its funding from US Government sources.

Working with the T&E Team and Confidentiality

Q1: How will the Test and Evaluation (T&E) team handle the fact that they will likely be supporting multiple teams? How can a company be sure that their ideas will be protected?

A1: The T&E team is experienced in providing services to multiple companies and universities simultaneously and keep everyone's intellectual property private and isolated from each other. The team is willing to sign non-disclosure agreements with applicants to assure confidentiality.

Q2: Has the T&E team worked with the government to provide Government Furnished Capability (GFC) before?

A2: Yes, the team has worked with several U.S. Government agencies in T&E roles, including providing Government Furnished Capability.

Q3: How do proposing teams request GFC?

A3: Please send email to refer to dni-smart-epants-te@iarpa.gov and refer to the matrix that was shown in the introductory presentation. The presentation can be found on the SMART ePANTS IARPA site at https://www.iarpa.gov/research-programs/smart-epants under the section "SMART EPANTS GOVERNMENT FURNISHED CAPABILITIES (GFC)".

Q4: How much detail should proposers provide when asking for the letter attesting that a requested capability is reasonable?

A4: Provide sufficient detail to enable the team to reasonably assess the scope, timeline, and risk of what it requested. If additional information is needed, the T&E team will contact applicants to request details/clarification.

Q5: Is the email and subsequent discussion requesting specific GFC public?

A5: Private communications between applicant teams and T&E regarding requests for, detailed discussions of, or furnished GFCs will not be made publicly available. If a new GFC capability is described during the conversation, or details concerning a capability could be perceived to provide an advantage to applicants, that description will be published to the public.

Q6: If a proposing team asks for something beyond what has been done, how will the GFC team handle it?

A6: The T&E team will assess whether the requested capability is a reasonable adaptation of work that has already been paid for by the Government. If it is, they will provide a timeline and assessment of risk. If it is not, they will inform the proposer that they will not be able to provide the requested capability.

Q7: If MITLL/AFFOA receive multiple inquiries for the same capability, will they coordinate teaming with other groups with various capabilities?

A7: No. It is the responsibility of the individual offerors to form their own teams. Neither IARPA nor the T&E Team will provide guidance or recommendations on team formation.

Q8: Can proposers rent time to come in and use the equipment?

A8: Direct use / renting time on the equipment is not part of the offering.

Q9: What is the timeline for requesting GFC?

A9: The deadline for initiating a GFC discussion with MITLL is August 23, 2022. The team will commit to providing a capability letter by September 3, 2022 at the latest. Earlier requests are appreciated.

Q10: How much budget does the MITLL/AFFOA team have for GFC?

A10: Details of the GFC budget are private between the MITLL/AFFOA team and IARPA.

Q11: Would it be reasonable to request fabric advisory support from the T&E team?

A11: T&E team is not authorized to provide recommendations or advice to applicants on fabrics during source selection.

Q12: What is the overlap between MIT Lincoln Laboratory and AFFOA for the SMART ePANTS program?

A12: MIT Lincoln Laboratory and AFFOA are an integrated team for the SMART ePANTS program, and are referred to here as the T&E team. Capabilities at both locations are available for use on this program as described in the BAA.

Q13: How will the T&E team interact with proposers after selection?

A13: Financially speaking, selected and contracted performers will have a contractual relationship with IARPA. The T&E team has a separate financial relationship with IARPA. No funding will flow between contracted performers and the T&E team. The performer and T&E team will typically be under NDA or other mechanism permitting full transparency and collaboration. For technical matters, contracted performers will have regular contact with both IARPA and the T&E team.

Q14: Is there a separation between GFC and T&E?

A14: There is no separation between GFC and T&E teams. Staff working for both capabilities are referred to as the T&E Team.

T&E Team Intellectual Property

Q1: What background IP is part of the Government Furnished Capability?

A1: A range of background IP developed under present and prior U.S. Government funded programs is being offered as GFC. This IP includes patents and know-how developed by MIT Lincoln Laboratory, AFFOA, and third parties from projects that were government funded over the past 5 years. Please see the GFC capability list in Section 6.B.5 of the BAA for the full list of capabilities being offered.

Q2: How would future commercial licensing work?

A2: Please refer to the BAA for conditions pertaining to any developed capability under Smart ePANTS. Additionally, commercial licenses that make use of GFC will typically be non-exclusive, will be negotiated on a case-by-case basis at a later date,

and will come with an expectation of U.S.-based manufacturing, per T&E team regulation.

Q3: Does the T&E team have IP related to weaving technologies?

A3: The T&E team does not have published weaving-related patents.

Test and Evaluation Procedures

Q1: Can the performers submit samples for testing during program execution?

A1: Yes, in addition to the defined end-of-phase testing, selected performers may request additional intermediate testing from the T&E team in their proposal.

Q2: What is the lead time between swatch shipment and when test results would become available?

A2: The availability to report on testing results is contingent on instrumentation availability, but the T&E team plan to return testing results as quickly as possible. Interim testing is available if requested in the proposers' application, and specified during contracting.

Q3: Will T&E capability be available for other projects?

A3: Questions regarding testing outside of the IARPA SMART ePANTS program are outside the scope of this BAA.

Q4: Can performers get access to the standards documents referenced in the BAA?

A4: The standards documents may be purchased from the relevant standards organizations. A testing manual for the program will be provided to selected performers prior to testing.

Q5: Can performers be present during testing?

A5: Performer presence for testing may be allowed by IARPA at the sole discretion of the government, to be determined closer to the time of testing.

Q6: Can preliminary test results be kept private?

Test results will be made available to the performing team, to IARPA, and its government colleagues. No further dissemination is planned at this time.

Q7: Would interim tests and the testing plan be brought up in later negotiations?

A7: Yes, testing methods and times will be discussed during post-selection negotiations.

Q8: Do all 5 swatches at the end of Phase 1 need to be fully functioning and satisfy all comfort metrics?

A8: It is the expectation of the program that all swatches and garments required at each waypoint satisfy the metrics as described in the BAA for each phase.

Q9: What is the testing order for comfort and durability?

A9: The specific order of testing will be presented to performer teams at the program kickoff meeting.

Q10: Are the tests done with the full system including different environmental conditions?

A10: Yes, the tests are done with the full AST system that the performers submit, and the tests will include environmental components. Please see the BAA for details.

Q11: What are the metrics of the test?

A11: Please refer to the BAA Table 1 and Section 1.E.1.

Q12: Can performers request testing to be performed under additional conditions?

A12: IARPA will not provide testing for performance that is outside the scope of the BAA.

Q13: Some of the ASTM tests require a very specific sample size. Are there plans to modify them depending on the test with regards to changes to the wiring system?

A13: IARPA will negotiate the specific conditions for AST testing with performers after selection.

Q14: What does the system need to survive to avoid causing harm to wearers? To what does it need to comply? Are there materials that are not permitted for use?

A14: Please refer to BAA Section 1.C for a list of prohibited materials. This section also prohibits testing on humans in this program.

Q15: Are there any safety guidelines with respect to batteries?

A15: Per BAA Section 1.C, products produced must be able to operate safely. No further specifics are described.

Q16: Are there any requirements for software interfaces and connectorization?

A16: Per BAA Section 1.3.1, Offloaded data shall be readable by some external device, with documentation and procedures for data extraction, processing, and synchronization provided to the government for all ASTs delivered. Per BAA Section 1.C., ASTs employing commercial rigid interconnects for data export are out of scope.

Q17: What are the sizes of the swatches?

A17: Please see BAA Section 1.E.4. for information on swatch sizes.

Q18: Will performance tests be repeated?

A18: Please refer to BAA Section 1.E.1. - "During each program phase, the T&E team will conduct five (5) Sensing Event tests for a Performer's AST. Three Sensing Events before and two after comfort and durability testing."

Q19: Will EMI testing be done?

A19: No. However, the offeror may highlight advantages of their solution such as Electromagnetic Interference robustness in their proposal.

Q20: Will fabric tests be separated from sensor tests?

A20: No. The T&E team will perform all the tests on performers' ASTs.

Q21: Do performers need to submit components smaller than swatches?

A21: No.

Q22: Will testing be out of band with production?

A22: The availability to report on testing results is contingent on instrumentation availability, but the T&E team plan to make every effort to return the testing results as quickly as possible. Interim testing may be available if requested by the applicant in their proposal.

Q23: Do performers need to integrate the fiber into the swatch for testing?

A23: The BAA requires swatches to be provided to the T&E team at the end of Phase 1. Swatches will be tested according to the procedures listed in BAA Section 1.F.

Q24: Is there testing while a human is wearing garment?

A24: Per the BAA Section 1.E.2, there will be no human testing conducted in this program.

Q25: Are the standards provided in the BAA a guideline or are they strict requirements?

A25: Test plans for the program will be based on the standards identified in the BAA. Testing details will be negotiated with the government on a case-by-case basis.

Q26: Is it preferred for a performer to address multiple tracks?

A26: Per BAA section 1.E.1 - "Those who propose ASTs that respond to more than one Track with the same device will be viewed more favorably."

Q27: At what point do IARPA get updated about the test results?

A27: The T&E team will provide testing results to IARPA upon request at any time during the program.

Q28: Is there separation between GFC and T&E?

A28: No separation is anticipated between staff working on GFC and T&E.

Q29: Can the material be integrated but obscured/not seen for Phase 1?

A29: Materials may be integrated by any method that meets the deliverable requirements described in Section 1.F of the BAA.

Q30: Where will T&E be performed?

A30: Testing will be performed by the T&E team in their laboratories.

Q31: How should AST operating procedures be shared with T&E team?

A31: Regular technical discussions between contracted performers, the T&E team, and government are planned during the course of the program. Project data may be shared at any time during the contracted period.

Q32: Will performers receive their test swatches back?

A32: Test swatches will be retained or returned at the discretion of the government.

Q33: Can different types of fabric be used in the same garment?

A33: Different fabrics within the same garment may be used.

Q34: Who provides reference fabric and ASTs?

A34: Per BAA Section 1.E.4, reference swatches and garments are provided by the performer.

Q35: Are there different types of reference fabrics?

A35: Per BAA Section 1.E.4 reference swatch and garments should resemble those being used for ASTs. Garments should be a "primary garment" as defined in BAA Section 1.A.1.

Q36: How will electrical testing be carried out?

A36: Performers shall provide operating instructions to the T&E team. The T&E team will work with performers to make sure proper procedures are followed during testing.

Q37: Will the geolocation testing be indoors or outdoors?

A37: Geolocation testing will be done indoors according to conditions specified in BAA Section 1.E.1.

Q38: Can the geolocation AST harvest other signal opportunities?

A38: Per BAA Section 1.E.1, "Systems may employ images or signals from onboard cameras or antennas as a reference to aid in location determination if desired (such as office furniture, lighting, stationary signals of opportunity (e.g., Wi-Fi routers or computer Telecommunications Electronics Material Protected from Emanating Spurious Transmissions, TEMPEST, emissions)), but those reference points will not be known prior to testing. If desired, the Offeror may request a system calibration be performed to establish a point of origin one hour prior to performing a sensing event."

Q39: With regard to geolocation testing, how are these tests going to be determined given that the information is not always available (e.g. visual aids)? For example, visual aids may be located in a challenging environment or location, like a building.

A39: Testing conditions for geolocation are described in Section 1.E.1.

Q40: How will skewness/distortion be measured against reference material? Is bubbling being considered? Will skewness have increasingly restrictive requirements in subsequent phases? Which test is skewness involved with? What guides stretch/compression testing? Are there any proxies for evaluating sharp edges on the components during washing testing?

A40: Generally, performers should assume that the methods described in the testing standards provided in Table 1 of the BAA will be followed. Specific questions regarding testing techniques will be decided after the government has selected performer programs.

Q41: Is stretchability compared to the reference fabric?

A41: Yes.

Q42: Will the testing be done using the Kawabata method?

A42: Please refer to BAA Table 1 for standards used for each test. Kawabata (KES-F3) is used for the compression test.

Q43: How is comfort assessed in the tests?

A43: Please see BAA Table 1 for a list of program Comfort and Durability tests.

Q44: Will the samples be fully dried before performance evaluation?

A44: Yes. Per BAA Section 1.E.4, samples will be washed, followed by "an 8-hour line dry at 30% relative humidity indoors at 25 ºC".

Q45: How will the T&E team handle connectors for washing and other durability tests?

A45: Performers shall provide operating instructions to T&E team. The T&E team will work with performers to make sure proper procedures are followed during testing.

Q46: Is there a specific solvent that will be used in the wash test?

A46: Per BAA Section 1.E.4, samples will be washed, "for 30 minutes in water at 20 ºC in a top-loading washing machine."

Q47: What U.S.-based labs are you aware of that provide Kawabata testing?

A47: The T&E team will not make recommendations regarding teammates during source selection.

GFC Capability 1: Filament Draw

Q1: What are the minimum and maximum fiber size you can produce using the thermal draw process?

A1: **Typical fiber diameters range from 100 µm to 1 mm depending on the application. For embedding chips during a fiber draw, chip size dictates fiber size, e.g., if embedded components are 150 µm diameter, then the fiber is approximately 200 µm. There are no other direct limitations to drawing fibers under 100 µm in diameter, but note that surface energy affects the fiber more at that size. A detailed overview of GFCs available can be found on the SMART ePANTS page (https://www.iarpa.gov/research-programs/smart-epants) under the "SMART EPANTS GOVERNMENT FURNISHED CAPABILITIES (GFC)" section.**

Q2: *Is the fiber draw process is designed to preserve component structure? Is this a method that can be used to miniaturize component features?*

A2: **Yes, the process is designed to preserve the structure of the preform in the fiber, so mm-scale features become micron-scale features. Both surface and interior features can be preserved.**

Q3: *Is it only possible to draw a single polymer at a time, or can multi-material fibers be drawn.*

A3: **Multi-material fibers can be drawn, but they must have compatible melt temperatures. Items that do not melt can also be introduced, such as wires.**

Q4: *Why are preformed blocks rectangular prior to filament draw?*

A4: **If chips are being integrated, either in-draw or post-draw, it is advantageous to have a rectangular fiber. Typically, the components are not as small desired, and may have one in-plane dimension that is longer than the other. Further, in some applications a certain side of the fiber should be facing out. All of these things are made simpler by a ribbon-shaped, i.e., rectangular cross-section fiber.**

Q5: *Can fibers be produced with circular cross-section?*

A5: **Yes. A circular cross-section preform was described in the T&E Team presentation on GFC. Any shape is possible, although circular and rectangular cross sections are the most common.**

Q6: *Can a fiber with embedded devices be knit or woven?*

A6: **Yes, the fiber can be treated as a normal textile fiber, although in some cases the machines must be adapted to accommodate drawn fiber. Please see subsequent sections on knitting and weaving.**

Q7: *How are the preforms made?*

A7: **The preforms are made using any number of standard macroscale fabrication techniques, including machining, molding, additive manufacturing, drilling, etc. Thin-film deposition is also used to deposit coatings within layers of the preform.**

Q8: *Can there be open channels in the preform and are these preserved during the draw?*

A8: ***Yes.***

Q9: Are the preforms just made of polymer or is there a solvent?

A9: There is no solvent.

Q10: What kinds of materials would be compatible?

A10: Materials that melt when you want them to, or conversely, don't melt if you don't want them to. If you have embedded electronics that will go through a heat cycle, you must also think about temperatures that those components can survive.

Q11: Can different materials for a preform be used?

A11: Yes. The T&E team will provide a risk assessment of any requested material.

Q12: When drawing the fiber, what are your metrics for quality control?

A12: The T&E team will have in-line metrology during fiber draw that actively monitors spacing between wires and position of components, if they exist. Optical properties, if relevant, are also monitored real time, as is overall fiber diameter. Generally, the process has very good reproducibility and control of fiber size, tension, stress, temperature, wire pitch, and device spacing. Post-draw QC measurements for strength (bend, tensile) and solder joint quality may also be performed.

Q13: Is it necessary to anneal drawn filaments?

A13: Not generally. If fiber stress manipulation is desired, this can be accomplished through application-specific heat treatment.

Q14: What are typical draw temperatures?

A14: Furnace temperatures are typically between 100-400°C, depending on material and application.

Q15: Are fiber draw temperatures damaging to embedded electronics?

A15: 280°C is a comfortable upper limit for fiber draws involving embedded electronics.

Q16: If a wire or strength member is co-drawn with the fiber, does it stretch?

A16: No, the wires and strength members do not melt, flow, or stretch appreciably.

Q17: Can conductive polymers be used as a conductor instead of a metal?

A17: Yes, conductive polymer is a tool within the T&E team capability.

Q18: Are copper wires introduced within the draw insulated?

A18: The T&E team typically uses uninsulated wire, where the fiber itself acts as the insulation, although insulated wire can be drawn as well.

Q19: Do embedded components undergo the same stress as the polymer around it?

A19: Generally, they do not.

Q20: For embedded components, what is the final deviation from predicted device position?

A20: The final position of components is equal to the initial position times the square of the draw-down ratio, ±20%. If more precise spacing is needed, component integration post-draw is recommended.

Q21: Can organic diodes be embedded in a fiber draw?

A21: Compatibility of any component with draw temperatures must be considered to use the fiber draw capability effectively.

Q22: Does the fiber maintain the same orientation as the preform? Are there ever twisting or other asymmetric defects?

A22: Yes, the fiber maintains the same orientation as the preform; it does not rotate. Twist can be intentionally introduced if desired.

Q23: Can applicants request preforms with notches cut for components to draw?

A23: Yes.

Q24: What is the design process for going to final fiber shape from initial preform?

A24: Many of the T&E team design rules for fiber shape have been published, but not all of it. The capability to manipulate fiber shape is offered to applicants as GFC.

Q25: Can stretchy fiber be drawn?

A25: Yes. Please see the elastomeric polymer examples described in the T&E team open house presentation. Note that in those cases, a strength member was incorporated to intentionally limit stretch.

Q26: What kind of elastomers have been drawn to date?

A26: Styrene-ethylene-butylene-styrene (SEBS) and elastomeric cyclic olefin copolymer (eCOC).

Q27: What are the limitations of strength members that can be incorporated into the fiber?

A27: Strength members must be able to survive the draw temperature without deformation. Kevlar and Vectran are typical materials.

Q28: What are the biggest restrictions on the draw process?

A28: To date, the diameter of the furnace.

Q29: Where is the preform located during the draw?

A29: At the top of the tower, then it is lowered during the course of the draw.

Q30: Have you ever drawn liquids in your draws?

A30: Yes, but this process is still under research.

Q31: How do you put on an outer coating?

A31: The team can either draw the fiber with a cladding right away or redraw through a liquid bath to apply the coating.

Q32: Realistically how many leads can be incorporated into a fiber?

A32: The highest feasible number is ten. Four is typical.

Q33: Who are the end-use customers for the fiber?

A33: The SMART ePANTS program is designed to provide cutting edge research. Specific customers for the research are not contemplated in the BAA.

Q34: What is the throughput of the fiber draw?

A34: Typical draw speed is 1-2 meters/minute, depending on complexity of the fiber.

Q35: Are there any materials that would not be allowed to use in your laboratory?

A35: All new materials would be reviewed by the T&E Environmental Health and Safety team. Assuming there are no toxicity issues, there are no limitations.

Q36: Is there permeability data for water and air through drawn fibers?

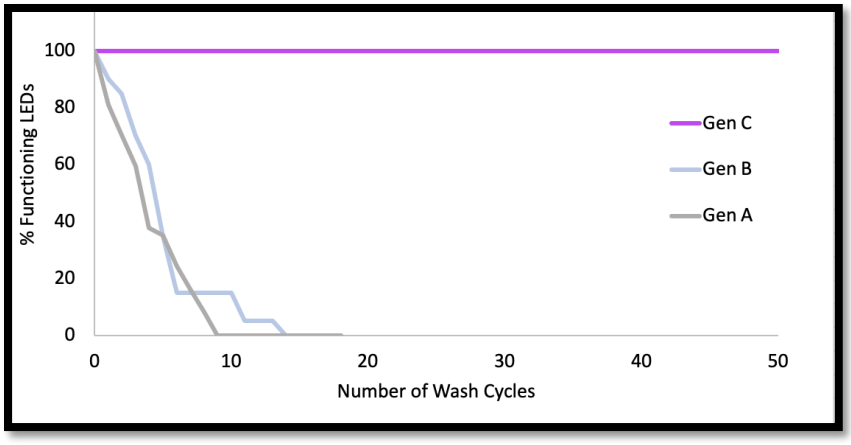
A36: The team does not explicitly have this, although several tests in fresh and salt water have been performed. Please note that the typical entry point for water is not through the bulk of the fiber, but through any interfaces and bonds.

Q37: Is SEBS waterproof?

A37: Please refer to the commercial datasheet for individual material properties.

Q38: Are the preforms and fibers washable?

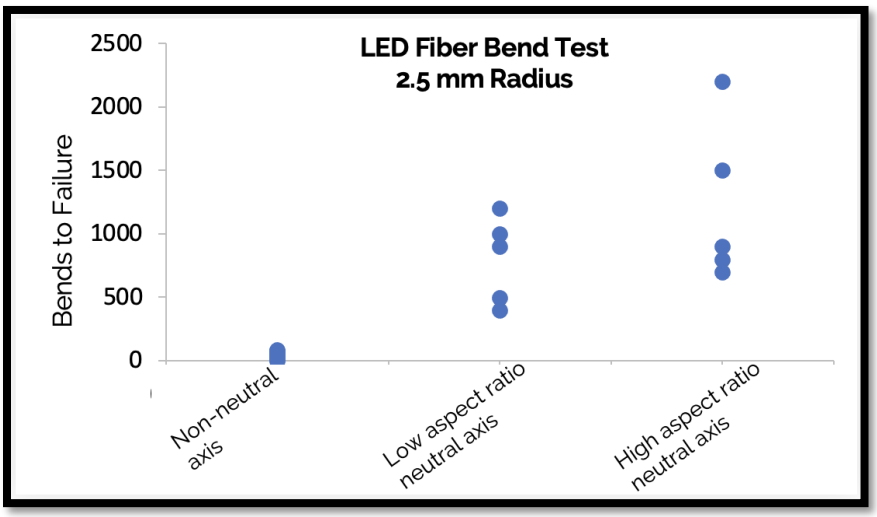
A38: The materials are, yes. The system design strongly affects washability. Please see the below example where the materials were the same, but the design was optimized for washability. Please note, the data shown is for water only, no detergent. Testing followed a modified ISO 6330 procedure.



Q39: Are there any environmental testing results you can share?

A39: Most T&E team test results are system specific and therefore private. Please see below for some generic bend test results. In this test, fibers are bent 360 degrees

around a 2.5 mm radius mandrel under constant tension and speed, repeated to failure.



GFC Capability 2: Yarn Twisting

Q1: *Why do some drawn fibers feel like plastic, while others feel more like conventional thread or yarn?*

A1: **The ones that feel like plastic are monofilaments, while the ones that feel more conventional have been wrapped or twisted with conventional yarns as multifilaments.**

GFC Capability 3: Weaving

Q1: *Can the looms handle elastomeric fiber?*

A1: **Yes, with accessory pieces of equipment. The team uses servo feeders that came with the Agteks DirectTwist yarn plying machine as well as unspooling options from Shima Seiki that can accommodate those fibers without introducing twist. The machines can be slowed down from standard manufacturing speeds to facilitate the use of elastomers.**

Q2: *Can pockets on the loom be created to handle larger devices?*

A2: **Yes, the team can design hems, pockets, channels, and other features to accept electronics.**

Q3: *Can the weaving process crush the components?*

A3: Yes, this can happen, but the team has developed techniques for getting the fragile components through fabric processes. Specific techniques are employed as needed on a case-by-case basis.

Q4: Can you rework or do you have to scrap material?

A4: This is highly dependent on the type of fabric, fiber, or component being integrated.

Q5: When fibers contain discrete components, is a map created first to track the location of the components in the fabric?

A5: This can be done if an automated process is being used. However, when using a hand loom, sensor location is determined manually.

Q6: How do you choose where the sensors land when using a hand loom?

A6: This happens either by eye, or if the components are very small, by machine vision.

Q7: Is there a minimum length of advanced material that is required for prototyping on each loom?

A7: This is dependent on how the fiber is integrated. For example, longer lengths are needed in the warp direction vs. the weft. Most prototyping with advanced materials will start with sampling in the weft direction, as less material is needed. Specifics are system-dependent.

Q8: How can wire breaks be prevented in woven textile?

A8: Typically, eliminating breakage is done by reducing weaving speed.

Q9: Can wires be reconnected if they break?

A9: This is system dependent. For example, if the fiber is tightly integrated into a woven textile and the break cannot be isolated from the finished fabric, it would not be possible to reconnect broken wires. In other scenarios, it may be possible.

Q10: How wide are the machines?

A10: Weaving width on the TC2 is 56 inches, CCi is 19 inches, and the AVL is 21-22 inches. Please see photos below.

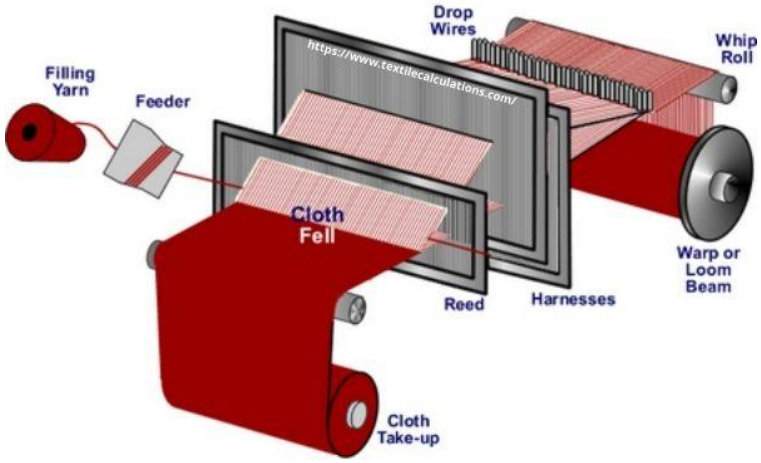
TC2 Loom

CCi Studio Loom

AVL CompDobby Loom

Q11: How are yarns fed into the looms?

A11: The warp yarns (the base of any woven fabric) are accumulated on a warp beam at the back of the loom. They are threaded through heddles (often on harnesses) which designate what types of woven design you can create.



https://www.textilecalculations.com/different-formulas-of-weaving-calculation/

Q12: Can you include anything in the weft direction during the process?

A12: Yes most new materials can be implemented at prototyping scale in the weft direction. The team has a standard evaluation procedure to de-risk introduction of new materials.

Q13: Do you do any research into seaming technologies? Like seam-taping? Or developing new ways to bond fabrics?

A13: The team has an ultrasonic welding machine in house, but seaming technologies are not a major focus.

Q14: What is the minimum pitch achievable in weaving with advanced materials?

A14: The fiber density or pitch depends highly on the warp materials chosen, their density in the reed, and the tension of weaving on the loom. All of these variables will affect how tightly the weft materials can be integrated in the final fabric.

Q15: Is the weaving designed or controlled using CAD software?

A15: Yes. Each loom has its own custom software, but they are translatable from loom to loom in bitmap format.

Q16: How does the pixelator/bitmap mechanism work?

A16: Each weaving file is a bitmap of 0s and 1s / lights and darks – a binary code – that tells the loom to raise or lower its harness or heddle. There are advanced programs that make the creation of this bitmap easier/more automated.

Q17: Is the pixelator a daisy chain or individually controlled?

A17: On the TC2 loom each heddle (or design file pixel) is individually addressable. For example, making and isolating a pocket in one area or your product would be easier on this machine with its jacquard capability. On the looms with harnesses (CCi and AVL), individual pixels are not addressable, and there is a more limited range of available functions.

Q18: Are you offering any unique or custom software to work with these machines?

A18: The software used by the team is commercially available. The GFC being offered lies in engineering/design experience with non-traditional materials.

Q19: If a team starts with doing its own fabric integration but runs into problems, can a team ask for GFC help later?

A19: The T&E team will be available to help performers execute their programs. Changes to GFC in a contract is open to negotiation with IARPA throughout the course of the program.

Q20: Can you guarantee components orientation in integration?

A20: Yes, machines can be slowed down to guarantee the orientation of component integration.

Q21: Is it possible to weave channels in garments and integrate special fibers post-process?

A21: Yes.

Q22: Can fibers be woven with integrated electronic components?

A22: Yes, either directly within the weave or in channels, pockets, multi-layers, or gauze weaves. Special fibers can be inserted either in the warp or weft direction, depending on specific characteristics.

Q23: What capabilities could be built into a 40-70 denier yarn?

A23: The answer to this question is dependent on the size and number of devices embedded in the fiber.

GFC Capability 4: Knitting

Q1: What are the options for integrating large components*?*

A1: In knit structures you can easily create pockets and channels, or different fabric thicknesses can be achieved in different areas of the garment.

Q2: Are there benefits to knitting over weaving?

A2: Knitting and weaving have different benefits. Knitting offers compression, stretch, and recovery. Knitting can be quicker and easier to set up. Woven materials tend to bend more easily and can be more durable.

Q3: For this project we have to pick a baseline material. If our baseline is a knitted material vs. a woven one, would the testing end up being different?

A3: Yes. The testing will be set up to compare to your baseline garment, whatever that may be.

Q4: Are you able to knit functional fibers without clogging the machines?

A4: Yes. There are many parameters that allow us to do this, and the technology continues to advance.

Q5: What kind of design tools are used to program and run knitting machines?

A5: Each manufacturer of each machine develops its own programming language and software. These can be quite complex and require a background knowledge of industrial knitting.

Q6: How do you insert conductive wires into a knit structure?

A6: The team does not directly insert wires. The team can incorporate functional fibers using an inlay or by warp knitting. Conductive fibers can be knitted.

Q7: Is full-garment knitting acceptable and practiced in industry?

A7: Yes, this is a common process, especially for foundational and athletic garments.

Q8: In both flat and WholeGarment™ knits, do you not feel the seams?

A8: No. This is a big advantage of these machines. Seams can either be linked to feel flat, or in the case of WholeGarment™, do not exist.

Q9: Are any yarns added after the garment comes off the knitting machine?

A9: Most yarns are incorporated during the knitting process, but multifunctional fibers are sometimes integrated after the fact into knit channels or pockets.

Q10: Do circular knitting machines strictly make tubes?

A10: Yes.

GFC Capability 5: Printing of Inks on Fabrics

Q1: What screen printing equipment was used to create the samples shown in the T&E presentation?

A1: The samples were created on an HMI MSP-9155PC Semi-Automatic Computer Controlled Screen Printer. However, there are many other commercially available machines that can perform the same process.

Q2: What conductivity can be achieved with the shown technique?

A2: Conductivity varies for each technology depending on inks/metals, base materials, and processing. The topography of the substrate also has a significant effect.

Q3: Can fabric withstand the temperatures required for metal processing?

A3: Temperature requirements are different for each technique, so you can tailor your fabric choices accordingly. For example with the evaporated metal samples, the metal is hot when it comes into contact with the fabric, but the fabric itself is at room temperature. Most of the samples shown in the Open House presentation were done at room temperature, with the highest temperature being 200°C.

Q4: Can ink be evaporated onto any fabric?

A4: In principle, yes, but when evaporating directly onto the fabric face, surface roughness and topography can influence the conductivity of the sample.

Q5: Is electroplating or sputtering available?

A5: Both techniques are available, but the T&E team has not applied them to fabrics.

Q6: When metal contacts the fabric, does it melt or form onto the surface?

A6: The adhesion mechanism is process and ink dependent.

Q7: What metals have been used to date?

A7: Copper has been used for the cut-and-peel technique, silver-based inks for 3D printing and screen printing, and aluminum for evaporated conductors.

Q8: For the sample with screen-printed silver ink, is there a minimum width required to adhere to the fabric?

A8: This parameter space has not yet been explored.

GFC Capability 6: Embroidery

Q1: *Were the circuits shown at the Open House done on the embroidery machine? What are some key parameters?*

A1: **Yes. There are several ways to do this. Conductive thread can be connected to PCB's via stitching through holes in the PCB or soldering. Wires can also be "wirelayed", or "fiberlayed" to attach advanced fiber to the surface of the fabric, and connect them to PCB's or chips. Multi-wire (or thread) buses can be made, but there are limits to how close together the traces can be. Limits will be determined by a combination of needle size, thread size, fabric texture, and whether the wires/threads are insulated. Additionally, the smallest step that the machine can take is 10 µm.**

Q2: *Have any of these structures been put through stretch tests?*

A2: **Not to date.**

Q3: *Is the machine shown in the Open House presentation commercially available?*

A3: **Yes. It is a ZSK JGVA.**

Q4: *What is the smallest feature size possible?*

A4: **See A1.**

Q5: *Have you embroidered fibers pulled on your draw towers?*

A5: **Yes. They can also be covered with conventional embroidery or stitching, or another layer laminated on them, so that they are not directly exposed on the surface.**

Q6: *How do you handle the cut ends of functional fibers?*

A6: **They are connected off the machine manually as part of a post-processing step, unless they are already integrated with a connector.**

Q7: *Are the wires used flexible?*

A7: **Metal wires are flexible, but if they yield they have shape memory. MITLL typically lay these materials down in a serpentine pattern to enable the fabric to stretch.**

Q8: *The pattern starts at one end, floats, then starts up again. How is this accomplished?*

A8: **The starting point is a vectorized layout file of the desired pattern (DXF, SVG, AI etc). Then the path taken by the embroidery thread can be engineered, for example to stitch a conductive via or make a mechanical or electrical connection to other components. Conductive threads can be covered with conventional threads in order to stabilize them against wear and oxidation, and to prevent them shorting against each other.**

Q9: *How precisely can interposers be registered?*

A9: See A1.

Q10: What is the team doing that is unique or proprietary?

A10: The ZSK JGVA machine is commercially available, but MITLL are stretching its capabilities by combining technical materials on it in new ways.

Q11: What is the difference between the capability shown and traditional embroidery?

A11: The techniques are similar to traditional embroidery, but with new materials. The ZSK JGVA machine represents the state-of-the-art tool for technical embroidery.

Q12: Are lightweight stretch knits possible to process on this machine?

A12: Yes, but they typically require a structural backing material in-process.

Q13: When doing embroidery, is there any potential for damage to wire from stitching?

A13: You have to develop the process to work with each material. There are many parameters that can be customized, including path, bend radii, spacing, etc. Once this is done for a material system the process tends to be very repeatable with few defects.

GFC Capabilities 7 & 8: Component Attach and Packaging

Q1: What are some of the embedded devices and how are they connected?

A1: Devices are application-specific. For embedded devices, connection is made as the wires come into proximity with metal pads on the devices. For more complex connection schemes, standard semiconductor assembly techniques are used post-draw, e.g., pick-and-place, flip chip soldering, wire bonding, etc.

Q2: Is it possible to use CNC milling to open a fiber and connect a part by hand?

A2: Yes. This would be considered low risk.

Q3: For post-draw integration, are there options besides solder to connect the devices?

A3: Yes: wire bonding, conductive adhesive, ultrasonic welding – any standard process used in the semiconductor industry is possible.

Q4: Is it possible to use underfill?

A4: Yes, although it is not often needed.

Q5: Are there any bus specs for the 4-wire fiber shown for the ocean sensing application?

A5: Fiber dimension: 1.3 x 0.3 mm. 4 copper conductors: 100 µm diameter, 300 µm center-to-center pitch. Cladding material: Ultem. 2 strength members: 100 µm diameter Vectran. This is one application-specific example and should not be regarded as a limitation.

Q6: What interposer materials are possible?

A6: FR4, polyimide flex, silicon, ceramic; anything available in the microelectronics industry.

Q7: What is the typical size of integrated electronic devices?

A7: Component size is minimized to the maximum extent available.

Q8: What is the purpose of the ASIC in the ocean sensing fiber?

A8: It handles communication to each individual sensing node.

Q9: Is embedding in a fiber better than direct fiber attach to a fabric?

A9: This depends on your system design.

Q10: Are fibers etched before bonding?

A10: It is not normally necessary, but all standard surface preparation techniques are available.

Q11: Are there environmental test results that can be shared?

A11: Unfortunately, these data are all system specific and owned by sponsors, so the T&E team are not able to share them publicly.

Q12: Are there specific requirements for connectorization?

A12: The methods to connect sensor devices in the swatch or garment should be described in the testing plan provided by the performer (See Q&A under T&E section above).

GFC Capability 9: Cut & Sew (Full-garment Integration)

Q1: Was the physiological status monitoring headband from the facility tour hand sewn?

A1: It was integrated using a combination of sewing machines and hand sewing.

Q2: What are secondary operations to make prototypes?

A2: Typical secondary operations include machine and hand sewing and a range of processes to integrate rigid components.

Q3: This work seems structured for prototyping, not manufacturing.

A3: That is correct. Many of the equipment and samples described by the T&E team were first-of-a-kind prototypes.

Q4: Since you are not standing up a full-garment assembly line, would this fall to the performers, to bring in their own cut-and-sew team?

A4: Please consult the BAA for details on number and type of samples required, and for information on how your team is evaluated.

GFC Capability 10: Encapsulation

Q1: *Is the encapsulant included during the draw or applied afterwards?*

A1: **Both ways are possible, depending on the application.**

Q2: *Is it possible to encapsulate or add water-resistant treatments to any of the shown printing methods?*

A2: **Yes. This is very common, and a variety of water-resistant finishes are available.**

Q3: *Can you provide specifications for the UV epoxy used?*

A3: **It is a commercially-available product with a datasheet available: https://dymax.com/products/formulations/light-curable-materials/encapsulating/9101**

Q4: *How much thickness is added by fiber encapsulation?*

A4: **This is system specific and can range from a few microns (e.g., a parylene coat) to several millimeters (e.g., epoxy hand applied at a node).**

GFC Capability 11: Sensor Interfaces

Q1: *What kind of cable was used in the camera shown in the Open House presentation?*

A1: **A micro-coaxial cable was used, but a parallel two-wire transmission line would have been another option.**

Q2: *What are some of the blocks available for sensor interfaces?*

A2: **Current blocks completed include analog-to-digital converters, amplifiers, and references. MITLL typically works in 22 nm or 40 nm nodes. Items that require adaptation to the needs of interested teams include bit depth, specific choice of node size, on-chip memory options for the node size, on-chip vs. off-chip memory options, power, and other architectural considerations. Since some of the blocks are procured externally, there is no pre-established list.**

Q3: *If there is functionality that's not in the ASIC, would proposers have the opportunity to add it in?*

A3: **As long as these blocks are available to the T&E team, or as IP blocks that can be procured, there is an opportunity to add it to the design.**

Q4: *What kind of chip design lead times can be expected?*

A4: **The lead time will depend on the complexity of the chip, but in general, the plan would be to have them available in the latter half of Phase 1.**

Q5: *Is the CMOS image sensor being offered?*

A5: The CMOS image sensor is not being offered as part of GFC. It is a commercially-available Omnivision chip (OV6948), obtained through 3rd party representatives.

Q6: Do the optics function at a specific wavelength?

A6: No, they are designed to operate over the visible spectrum.