GTU **Georgian Technical University**

Expression of Interest

to

join the ATLAS Collaboration

as

Technical Associate Institute

4 September 2021

The Georgian Technical University (GTU) requests to join the ATLAS as a Technical Associate Institute for an initial period of *five* years. Within the ATLAS collaboration, GTU will contribute to ATLAS software developments.

1. Background

GTU in the center of Georgia's capital Tbilisi is the largest technical University in Georgia [1] having rich traditions of study and research in engineering disciplines from early in the XIX century. 10 faculties, 21 scientific centers, and 13 affiliated research institutes, 1'176 professors, 442 PhD, 927 doctorate students, 75 researchers are performing scientific-research activities in the field of – Information Technologies, Cybernetics, Metallurgy and Chemistry, Nanotechnologies, Biotechnologies, Machine Building, Aeronautics, Civil Engineering and Architect, Communications, Power Engineering, Transport, Mining, and Geology.

The concept of GTU is based on the introduction of new organizational units for high-standard research and teaching, which will promote the establishment of institutional networks between higher education institutions at both regional and international levels. The new organizational units are the Interfaculty university structures of Doctoral and Master Phase (Graduate Schools and Colleges). High-ranking groups of researchers - (Excellent Cluster) Knowledge Transferring Structures that provide the identification of new research topics, their systematic support, and strengthening.

GTU joined STEM (Science, Technology, Engineering, and Mathematics) education. Together with San-Diego University GTU has enacted several programs in Computer Science and preparing the next generation of STEM professionals. Scientific activity financially supported by local and international funding agencies – GNSF, GRDF, CRDF, ISTC, STCU, TEMPUS, USAID. GTU has wide collaboration with companies – British Petroleum, Durapact, Boeing, Invensys, Schneider Electric, Siemens, and research organizations - CERN, KEK, GSI, JINR, Desy, SLAC, FermiLab.

GTU built 240 square meter fully furnished and equipped office infrastructure for collaboration with the ATLAS experiment at CERN, Geneva, Switzerland [2]. A special team of IT engineers involved in the preparation of the CAD models of the ATLAS detector; provided methodologies and tools for Simulation; participated in tasks for database organization and management; have acted together with collaboration parties in the development of Continuous Integration platforms for the LHC software.

2. Motivation

GTU has had a successful history of collaboration with ATLAS since 2004. A Group of GTU students joined to ATLAS Technical Coordination team for the migration of the Euclid 3D models into the CATIA v5 platform, according to the agreement AA177-04. The team provide the set of 3D CATIA models of the detector, which was used by the ATLAS as the first official DB migrated from the EUCLID. ATLAS confirmed successful execution of agreement AA177-04 in the special document - General Acknowledgement of Acceptance, signed on 16 March 2009 by the ATLAS management and GTU [3]. 12 GTU students were involved, and 5 students were invited by the ATLAS for a long term (>2 years) for this activity at CERN.

Starting from 2010 GTU signed a new collaboration agreement AA366/10 with the ATLAS software & Computing [4]. New methodology and tools were built for the development of the geometry descriptions for the GEANT-4 simulation [5]. 7 addendums were signed and successfully executed with the participation of the 27 GTU students. 6 GTU students have visited ATLAS. 3 Ph.D. and 8 MSc dissertations were prepared. 15 papers were published in the international journals with 134 participations in the ATLAS workshops and 58 presentations in the International conferences.

In 2016 GTU and ATLAS signed Addendum No.3 to Protocol P119 for the fabrication of the Aluminium frame of the New Small Wheel in Georgia. Construction was successfully fabricated, assembled in Georgia "Elita Burji" factory, and delivered at CERN. The project was paid for and technically supervised by the GTU.

Becoming an ATLAS Technical Associate institute will

1. Promote the creation of innovative methods and tools for geometry modelling and implement them in the ATLAS experiment
2. Promote the development of the latest technologies of software applications development and their implementation in the ATLAS experiment
3. Grow up the research activity at GTU and number of students involved in the ATLAS projects
4. Further develop existing technical strengths at GTU
5. Gain recognition of GTU as a reliable and effective partner for international collaborations.

3. Technical Project Proposal

The following sub-section describes the projects GTU aims to engage in its objectives and work packages, deliverables, timeline and the anticipated duration of the technical association. GTU has been involved since 2010, in the R&D and production of the geometry descriptions for the simulation and development of cognitive software tools of visualization.

3.1 Technical Project Description and Objectives

ATLAS uses GEANT-4 infrastructure for the simulation. The data analyses show discrepancies between the simulated and real data for some regions of the detector. Precise simulation requires an accurate description of the detector geometry in GEANT-4. A number of studies done by GTU show that for some subsystems volumes are missing or are overestimated and wrong materials are assigned. GTU use CATIA for geometry description analyses, which enables cross-checking various geometries with the as-built geometries in the engineering database. Special chains developed by GTU permit the collection of the geometry descriptions from the various sources - Smarteam engineering, GEANT-4, XML, GeoModel, cavern background, Outreach visualization into one platform. GTU developed special methods and tools for the simplification of geometries for the simulation. They enable to keep the basic mass properties - weight and volume of the source as-built engineering descriptions unchanged in the simplified geometries [6].

In 2021 new method of radiation distribution study on the early stage of CATIA study was developed with cooperation of the Tile calorimeter group [7]. As a result, together with keeping the mass properties of the as-built descriptions unchanged, now it is possible as well to keep radiation length and absorption length in the acceptable range of distribution in the simplified geometries. Thus, it makes it possible to create precise geometry descriptions for the precise simulation. GTU has done *two* projects of geometry simplification based on the new method - LA Pump [8], LA valve [9] and By-Pass Tube in the GAP region and achieve in the simplified CATIA geometry unchanged weight, volume and absorption length dispersion within the 0.3λ.

The software applications for 3D visualization aim at the graphical representation of the detectors facilities. The Augmented Reality (AR) visualization is a highly demanded technology for outreach and visualization in HEP experiments. There are several implementations – AR table, enables to put detector on the discussion table by using of the portable devices; AR door – method for navigation inside of detector; AR book, visualize extention of the paper-printed materials; Virtual reality method, based on a realistic representation of the real-life scenes in 3D; Mixed reality method, mixture of the VR and AR. Mostly these kinds of applications are based on special graphical engines and special hardware. They require powerful computers and heavily depending on the software platforms. Therefore, their implementation is limited. Development applications based on the browsers with the implementation of the gaming engines make applications widely accessible, workable on the cheap hardware, free from installations and platform-independent. Usage of the gaming engines bringing a big advantage to the applications. However, visualization scenes of HEP are complex and gaming engines have limited possibilities. GTU team developed special methods and tools for finding the agreement between the limitations of the WebGL/three.js gaming engine and requirements for visualization of the ATLAS detector [10].

3.2 Description of the Work Packages

GTU wishes to contribute to ATLAS geometry description developments for simulation, to the development of cognitive software tools of visualization, as well as to the development of the software tools for the ATLAS software quality. These projects are organised according to four work packages described below.

WP01: ASCIG – Software Quality

The ATLAS Software and Computing Infrastructure Group (ASCIG) manages over 650 virtual machines utilising more than 5000 virtual cores for 50 different projects within ATLAS. ASCIG needs highly skilled and motivated Linux experts to help maintain and expand our existing infrastructure. The ideal candidate will have a strong understanding of computing security, standards, and compliance for designing large scale cloud computing solutions; also a variety of experiences working as an architect and systems or software or network engineer.

Initial tasks: Support CPPcheck and Coverity installations for ATLAS, and other central software services as needed

- Keep the current installations of CPPcheck and Coverity in working order and update the packages as needed
- Run the automatic CPPcheck scans and associated tools to report the errors found to the authors of the relevant software packages
- Set up automatic Coverity scanning processes, integrated with Gitlab and other tools used by software developers.

Longer term: Participate in the operation of central services and develop customised solutions for future needs.

This work is foreseen to be done on an initial 2 years period with the possibility for extensions.

FTE assigned: 1.0

Duration: 5 years

WP02: Outreach & Education Group

Development of an augmented reality web-based visualisation software for the ATLAS Collaboration.

This package would entail several different components that include an Augmented Reality Table (ART), an Augmented Reality Book (ARB), an Augmented Reality Landscape (ARL) as well as an Augmented Reality Door (ARD) application. This set is completed by Tracer/VR, a web-based application for the virtual tours of Point 1.

All of these applications will be developed for the benefit of the ATLAS Collaboration and, together with all required dependencies, be made available as Open Source software with an ATLAS-compatible license either via the ATLAS GitLab at CERN or a similar platform with equal open access in the future.

The work on the applications should be in close collaboration with the ATLAS Education & Outreach group, with regular updates in the weekly meetings, to collect input on the education and communication aspects of the various projects and for final approval and public communication of the products as ATLAS communication tools.

Tracer/VR is a web-based application for the virtual tours of Point 1, including the exterior/interior civil-engineering infrastructure, services and detector components. The main characteristic, which makes Tracer/VR differ from the other similar applications is the low requirements on the hardware components, compatibility to most/many platforms and no required installations. All those will make the application widely accessible and usable by a large number of people. The application will run on ordinary mobile phones equipped with low-cost Google cardboards. Specially developed geometry descriptions will ensure high performance and high quality of the 3D scenes. The Point-1 civil-engineering descriptions will be developed from existing CAD models and added to the baseline geometry.

The geometry descriptions of the Point-1 civil engineering and services will be developed from existing CAD models and delivered at the end of 2022. A fully developed version of Tracer/VR will be available by the end of 2023 and will include pre-scenarios of virtual touring like touring inside the Muon system, or Calorimeters, etc. The Drone flying scenarios following a guide on the blue structures, stairs, and floors. Selection of subsystems and getting detailed information about functionality and construction history, etc.

Augmented Reality Table (Tracer/ART) will be a tool that permits to 'put' a scaled model of the ATLAS detector on a table for presentation and discussions. The detector will be visible through mobile devices. It will be possible to share a 3D scene from one device to another. A first draft of ART is already developed and available on the Tracer website (https://tracer.web.cern.ch). This draft is based on a special engine, Vouforia and is platform-dependent. First priority will be given to web-based engines (three.js, Unreal engine), to make the ART application platform-independent. Therefore, R&D work will be done on the first stage with the main subject to find ways to ensure the acceptable performance of the application and the high quality of the scene. That can be achieved by the selection of the "right" engine and the development of methods for simplification of 3D scenes. This R&D work requires test runs of various engines with various scenes with different geometry complexities and finding the best ways for the application development. In a second stage, a prototype of the application will be developed with just basic functionalities, such as detector representation and assembly/disassembly of the components. In a third stage, extended functionalities for the interaction with the detector will be developed. For the ART application we should reach the first stage by 2022, the second stage by 2023 and the full functionality by 2024.

Augmented Reality Book (Tracer/ARB) will be an augmented-reality extension for printed material –like books, ATLAS Cheat and Fact Sheets and posters. ARB will run on portable devices and will be browser-based. Users will be able to scan a QR code on the printed material to activate the application. Then ARB will recognise the subject of the paper and 'put' a fully controllable (Zoom/Rotate/Selection) 3D scene with animated objects on top of the printed material, extending the users' understanding of the subject of the printed material. The particular subject of ARB projects will be defined by the ATLAS Education & Outreach group. 3D scenes for the applications will be developed according to the materials of the related printed material.

For Tracer/ARB, geometries for the 3D scenes will be developed according to the materials of the related printed documents. The amount of work and duration depends on the complexity of the scenes. On average five scenes will be developed per year until 2026.

Augmented Reality Landscape (Tracer/ARL) is an application that will allow the user to 'put' a real-size ATLAS detector in the user's environment to get a better understanding of the detector size compared to the landscape. ARL will use detector geometry descriptions specially developed for this project. Priority will be given to a browser-based application. However, in case of performance issues, some other engines, like Unity will be implemented. The application will run on mobile phones and tablets. Therefore, R&D work is needed to find agreement between the platforms/engines possibilities and the requirements of visualization of the detector systems. This research work will include searching the graphical engines best fitted to the requirements and developing the methods for the geometry representation.

The ARL application should be available by 2026, with developments starting roughly in 2025.

Augmented Reality Door (Tracer/ARD) is an application that would allow users to walk inside the ATLAS cavern and other detector facilities, which will appear in the real-life environment of the user. For entering/leaving the augmented reality rooms, virtual doors will be implemented. Then it will be possible to install the virtual door in the real-life environment – like an exhibition – and go through it with the portable device. In the virtual room, another door could be installed and used for entering into another virtual room, etc.

The full-functionality ARD application should be available by the end of 2026, with developments starting in 2024.

The complete Education & Outreach work package would extend over a period of five years and GTU will commit to providing person power equivalent to 2.5 FTEs over the full period – 2.0 FTE programmers and 0.5 FTE designer.

FTE assigned: 2.5
Duration: 5 years

WP03: Tile Calorimeter Group

Development of the Tracer/TCAL – the 3D Web-based Visualization Application

The Tile Calorimeter community would like to pursue a project to study and try new methods and functionalities of an interactive 3D web application with the visualization of the detector and its associated properties, including as-built geometry, raw data and calibration constants. This will allow to display and manipulate the quantities and geometry in various application domains like operational debugging and failure pattern extraction, calibration and maintenance of the hardware and expert training.

The requirements were prepared by the Tile Calorimeter community in close collaboration with the GTU team, including cells and modules geometry visualization with raw data, advanced scaling and filtering, display of the cabling and hardware identifiers, display of the calibration constant values per cell and channel.

The application will be based on the Tracer technology and will be developed and deployed in several releases during the two year period. The results will be presented and discussed at various levels of ATLAS meetings. The code will be developed and released in accordance with open source policy of ATLAS collaboration software development. Other visualization projects like GeoModelExplorer, Phoenix will be able to profit from this study by means of the code, expertise, and know-how.

FTE assigned: 1.0
Duration: 2 years

WP04: ITK

Cross-checking of Materials Description in the PP1 Region

The PP1 region of ITk has a very complex geometry. It is essential to have accurate geometry descriptions in that region for precise simulation of the forward region performance. It is proposed to provide a cross-check of the actual ITk simulation geometry with an "as-build" CATIA CAD geometry. Given its complexity, the PP1 region is particularly interesting for this initial analysis. Differences may be discovered in weight, volume, positioning, geometry configurations, and radiation lengths. The CATIA descriptions will be developed starting from the Engineering Databases of ATLAS and comparison analyses will be carried out by the methods and tools developed by GTU in CATIA. The GTU group has developed a unique method that enables to calculation and check of the radiation length in CATIA using non-simplified as-built geometry descriptions. This tool enables to make estimations of geometries on the early stage of development and provide checks of the existing simulation geometries.

The team of Georgian Technical University already discussed possible outcomes for ITk on the ITk Offline SW meeting 0n 19 Feb 2021 [11]. Another discussion was at the Simulation Group extended meeting on the 2nd of March 2021 [12].

This work is foreseen to be done on an initial 2 years period with the possibility for extensions.

FTE assigned: 2.0
Duration: 2 years

3.3 Duration of the Association

The association as Technical Institute should last until the completion of the work packages described in section 3.2. The work packages have different durations from 2 to 5 years with the possible extensions in case of mutual interests. Therefore, GTU propose an initial membership for five years starting from 2022 to 2026 including.

GTU is open to wider cooperation with the ATLAS and will be attentive to additional requests.

3.4 Deliverables and Milestones

In close collaboration with the ATLAS groups, GTU will contribute to the development of the software resources and geometry descriptions for the simulation. Deliverables and milestones are vary depending on the work packages and requirements of the ATLAS groups.

For **WP01** will be developed ATHENA scanning processes for CPPcheck and Coverity checkers and will delivered software modules for automation. The timeline for CPPcheck modules development is the end of 2022 and for Coverity, the end of 2023.

For **WP02** will be developed several AR/VR software platforms. For Tracer/VR the geometry descriptions of the Point-1 civil engineering and services will be developed from existing CAD models and delivered at the end of 2022. Fully developed Tracer/VR will be available by the end of 2023. For the Tracer/ART R&D work will be done on the first stage (end of 2022), a prototype of the application will be developed with just basic functionalities during the second stage (end of 2023) and during the third stage, extended functionalities for the interaction with the detector will be developed, like "hands" appearing as an active haptic tool in the scene. It will require additional R&D work (by end of 2024). For the ARB, geometries for the 3D scenes will be developed according to the materials of the related printed documents. The amount of work and duration depends on the complexity of the scenes. On average 5 scenes will be developed per year. For the Tracer/ARL, R&D work will be done on the first stage with delivering the prototype and the full functionality on the second stage. The project will be a 1-year duration with an ending date at the end of 2026. The Tracer/ARD development will start in 2024 and the application with the full functionality will be delivered at the end of 2026.

For **WP03** will be developed 4 releases of the application - releases R1.0 and R2.0 in 2022 and releases R3.0 and R4.0 in 2023.

For **WP04** geometry descriptions of PP1 assemblies will be considered in the separate projects. Each project will foresee 9 consecutive stages of development. At each stage, deliverables will be technical reports of the geometry analyses and geometry descriptions in the CATIA platform and XML. On average 3 projects will proceed per year.

#	Application	Deliverables	Timescale
WP01	Cppcheck scanner	Automation modules for CPPcheck scanning of the individual merge requests; Automation modules for scanning and preparing results for full and incremental Coverty scans	Q4 2022
	Coverity scanner	Automation modules	Q4 2023
WP02	Tracer/VR	Geometry descriptions of Point-1 infrastructure and services	Q4 2022
		Full functionality application	Q4 2023
	Tracer/ART	R&D work	Q4 2022
		Prototype with basic functionality	Q4 2023
		Extended functionality	Q4 2024
	ARB	Five 3D Scenes per year	Q4 2026
	Tracer/ARL	R&D work	Q4 2025
		Full functionality application	Q4 2026
	Tracer/ARD	Identification and development of virtual room contents	Q4 2024
		Development of 3D geometries of virtual rooms	Q4 2025
		Development of the AR navigation functions in the virtual rooms	Q4 2026
WP03	Tracer/TileCAL	5 versions of R1.0 and R2.0	Q4 2022
		5 versions of R3.0 and R4.0	Q4 2023
WP04	3 Assemblies	9 Stages per assembly	Q4 2022
	3 Assemblies	9 Stages per assembly	Q4 2023

3.5 Top level Work Packages

#	Description	End Date
1	ASCIG system administration and SQ checking	5 years
2	AR/VR applications development and maintenance	5 years
3	ITK PP1 geometry description, development and checks	2 years
4	TileCAL display application development	2 years

3.6 Resources

Name	Role	% of time on this project	Duration on project	Expertise	WP
Prof. SHARMAZANASHVILI Alexander	Coordinator	50%	5 years	Software development	All
Dr. SURMAVA Archil	Designer	50%	2 years	Geometry modeling	WP04
Dr. TSUTSKIRIDZE Niko	Designer	50%	2 years	GEANT-4 simulation	WP04
Dr. KEKELIA Besik	Designer	50%	2 years	GEANT-4 simulation	WP04
MSc TODUA Luka	Programmer	100%	5 years	Linux, WebGL/three.js	WP01
MSc SHEKILADZE David	Designer	50%	2 years	CATIA	WP04
ZURASHVILI Nino	Programmer	100%	2 years	WebGL/three.js	WP03
KVERENCHKHILADZE Irakli	Programmer	100%	5 years	WebGL/three.js	WP02
KOBAKHIDZE Shota	Programmer	50%	5 years	WebGL	WP02
ALIKHANOV Alexander	Designer	50%	5 years	CATIA	WP02
SHVELIDZE Irakli	Programmer	50%	5 years	WebGL	WP02

Prof. Alexander Sharmazanashvili will coordinate the execution of the work packages. Dr Archil Surmava, Dr Niko Tsutskiridze, Dr Besik Kekelia, and PhD student David Shekiladze will be responsible for the geometry description development for ITK. PhD student Luka Todua will participate in Linux and programming of the SQ modules. MSc student Nino Zurashvili and Irakli Kverenchkhiladze will involve in the 3D Web display application development. Shota Kobakhidze, Alexander Alikhanov, and MSc student Irakli Shvelidze will develop 3D scenes for AR/ARB applications.

Students from GTU are also expected to contribute to the work packages under the supervision of the above-mentioned personnel, initially at a small (5%) percentage that will rise with the progress of the packages.

4. Operation and maintenance

GTU will share the expertise, documentation and software developed during the association. GTU will provide new technologies for the preparation of the geometry descriptions and development of the 3D cognitive web-based software applications. Knowledge will be transferred via regular meetings, and technical reports, participation in the ATLAS workshops.

The software developed in the framework of the association is and remains accessible to and usable by the ATLAS collaboration, also when the association with GTU may be finished. The software will be fully open source under the license acceptable in the ATLAS collaboration.

The prolonged association is possible in the case of mutual interests.

References

1. https://www.gtu.ge

2. "ATLAS S&C Meeting 25 April, 2019 Status of Agreement AA366/10" https://indico.cern.ch/event/815503/

3. "General Acknowledgement of Acceptance"/ The ATLAS Collaboration, 16 March 2009

4. "Provision of Level of Effort in the Area of Software Development for the ATLAS Experiment"/ ATLAS Agreement No. 366/10, 2010

5. "GEANT-4 Geometry Descriptions Study"/Report from the Georgian Team, Muon Software Meeting 14 March 2019 https://indico.cern.ch/event/785991/

6. Sharmazanashvili A. "Modeling Aspects of Hyper-Complex Products in Nuclear Engineering Projects / Proceedings of TMCE 2012, May 7–11, 2012, Karlsruhe, Germany

7. Alexander Sharmazanashvili, Alexander Solodkov, Archil Surmava, Niko Tsutskiridze, Besik Kekelia "Using Radiation Length Analyses for the Early Study of Simulation Geometry in CATIA"/2021

8. "Investigation and Development of the LA-PUMP description for the Simulation"/ TileCAL Group Meeting 26 March, 2021 https://indico.cern.ch/event/1022690/

9. "Geometry updates for Simulation"/ TileCal Week Computing 18 June, 2021 https://indico.cern.ch/event/1046116/

10. Alexander Sharmazanashvili, Nikoloz Udzilauri, Shota Kobakhidze, Luka Todua, Nino Zurashvili, Irakli Kverenchkhiladze "Browser-based visualization framework Tracer for Outreach & Education"/vCHEP 2021

11. "Simulation Geometry Based on CAD"/ITK Offline SW, 19 February 2021
https://indico.cern.ch/event/1010013/

12. "Implementation of X0 / Lambda Calculations in CATIA Compare Analyses" / Simulation Group Meeting, 2 March 2021 https://indico.cern.ch/event/995920/