Model for Defence R&D Scientific and Engineering Software Development

B. N. Gajbhiye and V. Kamakshi Prasad

Abstract—Development of scientific software due to its nature faces different challenges compared to commercial software development. Challenges of developing such software and emerged models are discussed by the researchers in the literature. However, when the scientific & engineering software is developed in-house in defence research and development establishments for weapons systems, some more challenges are added. This research identifies the characteristics of such software, additional challenges and model followed in the development of defence R&D scientific & engineering Software.

Index Terms—Model for defence R&D software development, scientific software development, weapon system software.

I. Introduction

Development of scientific software has become an important topic of research as several publications on scientific software are appearing in the journals. Dedication of special issue, IEEE Software July/August 2008 also reflects the importance. Researchers have studied the aspects such as identifying characteristics of scientific software [1], distinguishing scientific software from commercial software [2], identifying risks [3] and challenges [4] associated in development and discussing the models used in scientific software development [5]. C. Carver Jeffrey *et al.* [6] in their paper presented a series of case studies on computational science and engineering projects and brought out the process used in developing such software. In this class of science and engineering applications, however focus is on the applications that uses high performance supercomputers. When the scientific software is developed for an engineering application in military, no of additional challenges are faced, particularly when the software is developed in-house. Development of such scientific software for a military engineering application neither fits fully into the development models of scientific software brought out by J Segal [5] nor into the models available for commercial software development.

The aim of this paper is to capture a model used by the scientific community in developing software for military weapon systems in the defence research and development establishments. What are the characteristics of such software and challenges associated developing the software are

discussed.

II. Characterisation of Scientific Software Development

Scientific software includes variety of software, such as high performance computing, complex simulation software etc. According to J. Segal and C. Morris [2], factors given below make scientific software development different from commercial software.

1) Scientists who is domain expert is mostly the developer of this software
2) Complete up-front requirements specification is not possible as requirements emerge with the understanding of the domain.

While C. Carver Jeffrey *et al.* [6] supported the requirements factor and specified following additional factors:

1) Teams mostly consists of domain scientists and engineers rather than formally trained software engineers
2) Main driver for the science project is not correct science or engineering but software quality achieved through good software engineering practices
3) Developer is not keen in following process based approach for software development. Reason could be partly lack of training in software engineering and partly due to application domain.

III. A Typical Organisation Structure in Defence R&D Establishment

Defence Research and Development Organisation (DRDO) consists of more than 52 laboratories spread all over in India and are engaged in design, development leading to production of weapon systems for the Armed forces of the country. Each establishment is specialised in certain military technology and headed by Director who is usually a scientist. A typical matrix organisation structure in establishment is shown in the Fig. 1. Weapon system design and development pertaining to the military technology domain is taken up by the laboratory/establishment. Project director is responsible to execute such project. Most of the projects are multidiscipline and collaboration with other organisations within and outside DRDO, with Academics and industry is required. Technology directorates are the specialised groups who carry out scientific research for developing technology necessary to the design and development of the project. At the same time, scientists carry out advance research for the futuristic technology requirements in their area and are at par in the field.

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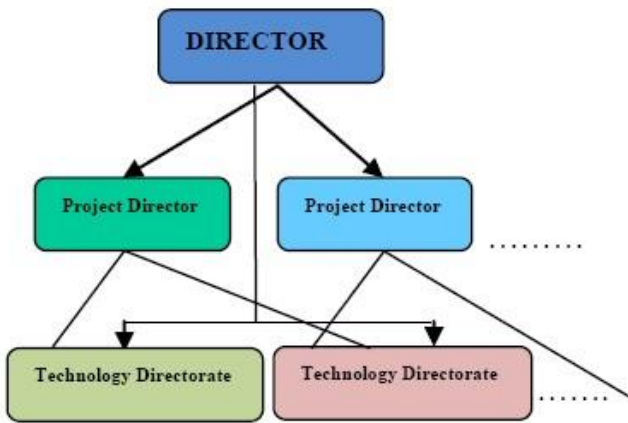
Fig. 1. Typical organisation structure.

A scientist from applicable technology groups becomes the part of weapon development project. Many times, scientists have to share their time by taking responsibility of multiple projects.

IV. CHARACTERISATION OF DEFENCE R&D SCIENTIFIC AND ENGINEERING SOFTWARE DEVELOPMENT

Defence Research and Development Organisation (DRDO) is engaged in design and development of Military Technologies leading to production for the Armed forces of India. This essentially requires carrying out scientific research in multi-discipline area and developing engineering solutions for the weapon systems. Following categories of software are developed during the design and development of any weapon systems in general and is not a complete list.

A. Simulation Software

Based on the requirements of weapons system, a simulation software is developed by the system scientists to study and establish the weapon parameters for the required performance and objectives of weapon. Simulation software also developed for testing, validation and training the users.

B. Weapons Sub-Systems Design Software

Weapon systems design and development is a multidiscipline activity and either software is developed or the specialised software package is used by the scientist for design and development of each sub-systems of the weapon. For example, for missile, aerodynamic, structure, propulsion, navigation, control, guidance, image processing etc. These are much specialised scientific software developed as a part of design and development of state of art technology or futuristic technology required to meet the objectives of weapon system.

C. Weapon System Software

This consists of software that goes on-board in the weapon.

D. Ground System Software

This software is an essential part of weapon system which facilitates testing of various sub-systems and launch of weapon system. Ground system software is also a part of weapon system software but does not fly.

All the above software is mostly developed in-house by the scientists and engineers.

E. Defence R&D Software

Defence research & development software, developed mostly in-house has the following characteristics.
1) Design and development of sub-systems evolves over a time and hence final details of hardware and sub-system design are not available till final sub-systems are ready.
2) Users of the weapons are the armed forces. Requirements for the weapon are either specified by the armed force or formulated in the project proposal by the project director but software requirements are evolved mostly in-house.
3) Weapon system software, being a mission critical; there is a need for independent verification and validation(IV&V) of the software
4) The software need to be maintained by the developer as long as weapon exists in the armed forces inventory

F. Scientific Software

Scientific software developed by scientists in specialised area has the following characteristics.
1) Scientific research in the various specialised area leading to indigenous development of high end technology is not time bound and without risk.
2) Outcome of scientific research is algorithms, engineering solution etc.
3) Domain scientists from the area such as systems, control, guidance, navigation, structure, aerodynamics and propulsion performs the design & development and develop the required software.
4) Design of the sub-systems is usually documented by the scientists
5) Scientists continue to work in the area of their specialisation and attrition or transfer to other establishment is very minimal.

G. Engineering Software

Scientific software developed by scientists in specialised area is used in sub-systems, also called engineering units of the weapon system the following characteristics.
1) Research output of the specialist either embedded or interfaced with engineering units
2) Development of engineering units of weapon system, where weapon system software resides or is a part of, is driven by the hardware design and development
3) Design and development of electronics engineering units and software is done by electronics and or software engineers

V. A MODEL OF DEFENCE R&D SCIENTIFIC AND ENGINEERING SOFTWARE DEVELOPMENT

Defence R&D Scientific and Engineering software development consists of developing simulation, weapon sub-system design software, weapon system software which include weapon related ground software and follows the associated characteristics as discussed in the section A, B, and C above.

Defence R & D Scientific and Engineering Software Development Model is a hybrid model where for certain

application research and development carried out by the scientists themselves; some other application hardware/software engineers joined the scientists in development; hardware/software engineers ; hardware(with electronics and communication) engineer and lastly by software engineer. Use of technologies and tools also varies.

A. *Weapon System Simulation Software*

The modeling and simulation of weapon begins with this kind of software usually carried out by the system scientists. Weapon systems requirements are the basic requirements based on which the simulation software is developed, tested for the objectives and performance and goes through the several iterations following the typical " Development by Scientist" model discussed by J. Segal [2]. However, the results of simulation software are presented, discussed, debated in the forum called system engineering meeting which comprises the scientists from the various disciplined and project office.

B. *Weapon Sub-System Design Software*

Research on sub-systems design and development starts once the initial acceptable system simulation model is ready and continues till design objectives are achieved. To carry out this research, scientists develop models, algorithms or make use scientific packages. Software is developed to test the sub-system design available in the form of models, algorithms etc. following the same model "Development by Scientist" discussed by J. Segal [2]. This iterations as shown in the Fig. 2 continues till the acceptable results are obtained and scientists are satisfied. Feedback of the sub-systems design given to the weapon system simulation software to refine weapon model. Sub-systems algorithms either becomes the part of on-board computer system or independent on-board sub-system.
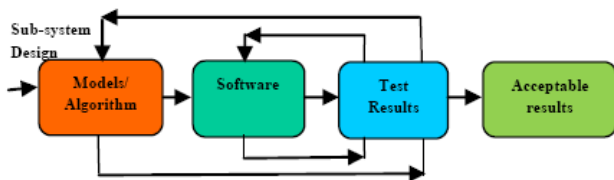
Fig. 2. Sub-systems software development.

C. *Weapon System Software*

This comprises of software residing in On-board computer as well as ground systems such as launch control, checkout, interface etc. Beside the on-board computer there could be other sub-systems like navigation, seeker, telemetry on-board on the weapon.

The on-board sub-systems and ground sub-systems design starts with design of hardware configuration similar to other sub-systems. Weapon system electronics hardware design is done by the hardware engineer, but software development could be done by experienced either hardware or software engineer. For getting such experience, a model of medical profession is followed, in which junior doctor is attached to the senior doctor for learning through observation and assisting with minor tasks. Once the hardware configuration is finalised, software development activity begins with identifying interface details and documenting the same in

Interface Control Document (ICD). Broadly, the functional decomposition done and architectural decisions taken are discussed in the internal meetings with the senior scientists and coding commences. The details from the other-subsystems start getting in. Re-usable modules are identified and included. Once the majority of functionalities are covered, testing begins. Then the testing and bug fixing continues, till the confidence in the software is build. Additional functionalities could also be added during testing and bug fixing iterations. Software verification and validation carried out concurrently as shown in the Fig. 3. Software engineering practices as brought out by SK Chaudhuri, K Sujatha and MV Rajsekhar [7] are followed. Verification & Validation of software is an essential activity for the engineering unit software. The validation of On board mission software is carried out in Integrated Hardware in Loop Simulation (HILS) environment validating flight software and hardware [7]. The design and development of hardware and software is essentially carried out by electronics and or software engineers and verification and validation of such software is mandatory in the model named, "Development by Engineers".
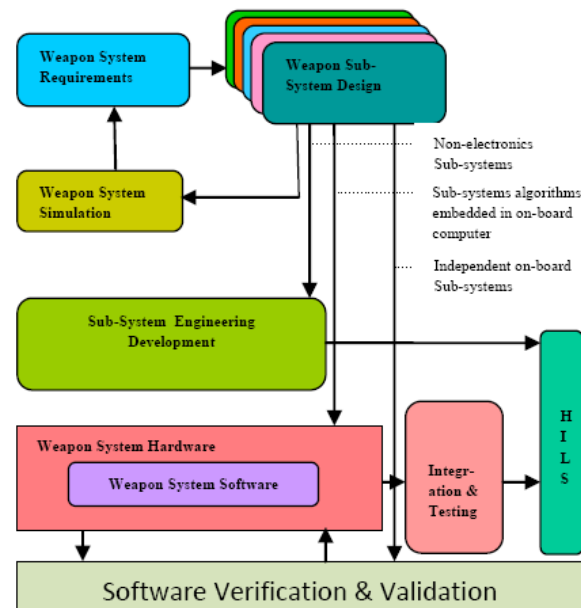
Fig. 3. Defence R & D scientific and engineering software development model.

VI. DISCUSSION

In a Defence R&D environment where scientific research is pursued and applied in the development of weapon system, pure model of scientific software development is not adequate. The model further has been augmented with "Development by Engineers" model to produce reliable weapon system software. The model has been proven very successful in developing reliable weapon system software.

VII. SUMMARY

Design and development of Military Technologies for the Armed forces of India is the responsibility of Defence Research & Development Organisation. Scientific research

in multi-discipline & developing engineering solutions required for the weapon systems is essentially carried out by the scientists. Hybrid model consisting of "Development by Scientists" for weapon simulation, sub-systems design and V&V augmented "Development by Scientists" model for weapon software which is called "Development by Engineers" model. Software in Defence R&D environment has unique characteristics which is different from scientific software is brought out and reflected in the model.

VIII.   ACKNOWLEDGMENT

REFERENCES

[1]   H. T. Li and H. D. Wang, "An Ontology-based process model for scientific research software development," in *Proc. 2010 2nd International Conference on Software Engineering and Data Mining*, pp. 299-304.

[2]   J. Segal and C. Morris, "Developing Scientific Software," *IEEE Software*, issue 4, July-August 2008, pp. 18-20.

[3]   R. Sanders and K. Diane, "Dealing with risk in scientific software development," *IEEE Software*, issue 4, July-August 2008, pp. 21-28.

[4]   C. Morris and J. Segal, "Some challenges facing scientific software developers: The case of molecular biology," in *Proc. 5th IEEE International Conference on e-Science*, 2009, pp. 216-222.

[5]   J. Segal. (2008). Models of Scientific Software Development. *Workshop Software Engg in Computational Science and Engg*. [Online].   Available: www.cse.msstate.edu/~SECSE08/Papers/Segal.pdf.

[6]   J. C. Carver, R. P. Kendall, S. E. Squires, and D. E. Post, "Software Development Environments for Scientific and Engineering Software: A Series of Case Studies," in *Proc. the 29th international conference on Software Engineering*, 2007, pp. 550-559.

[7]   S. K. Chaudhuri, K. Sujatha, and M. V. Rajsekhar, "Real Time Mission Software for a Missile Systems," in *Proc. International Conference on Avionics Systems*, Feb. 2008, Hyderabad.

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