University of South-Eastern Norway

Institute of Science & Industrial Systems,
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NAGINI

Project management plan

by

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June 1, 2020

Abstract

This document outlines a project management plan (PMP) for the development of a robotic snake; Nagini. An accompanying systems engineering management plan (SEMP) and prototype documentation, can respectively be found in [1] and [2].

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1 Project Description

Snake robotics play a crucially important role in everyday matters, from patrol to handling potential explosives. In many countries, Defense Forces are initiating the Snake Robot projects to strengthen their force and put forward the research and development (R&D) groups. These projects will result in the event of a kind of Snake Robots which may provide support and perform difficult tasks for the Defense forces in a way which is otherwise hard or impossible to do it. This may end in improved productivity within the defense forces. While Snake Robots are currently available, but many countries believe that new technological developments will enable our human resource to try to their job in a far superior manner to what's currently available in term of other support equipment. See [3].

In this project the main aim is to create a robot which can move very similar to the snake movement. The Project is divided into three different phases. In the first implementation phase, the snake robot will be going to move from the arbitrary starting point A to Destination point B on a flat surface. In the second phase of the project, Snake Robot will follow the object which is not defined beforehand within the specified range. In the third and final phase, the Snake Robot will move between the two points which are either predefined or not. The Snake Robot is equipped with a camera and sensors to make it possible for the robot to detect the destination or the object.

2 Project Planning Approach: Rolling-wave

A proper and flexible approach for managing a given project is essential for successful project completion. Unwanted (and wanted) emergences are bound to rise, and a method of countering them involves continuous, iteration-based planning. In addition, an iteration-based approach for managing a project interfaces well with the fundamentals of systems engineering. The project team chose one such approach; the "Rolling-wave" planning method described in [4] and [5].

Rolling wave planning is the concept of progressive elaboration (see [6]) applied to project planning. This means that initial project plan at project initiation will be a lowly-detailed plan since not many factors are known. As time advances and project-relevant factors of a life-cycle stage become known, the project plan gets reiterated and updated. See Fig. 1 for illustration. This enables the ability to tackle encounters with unwanted project- or system emergences since planning happens continuously. It is worth to note that project planning in general is not only performed during the general "Project planning" stage. Rather, project planning spans over the whole life-cycle of a project. Continuous project planning contributes to significantly higher chances of project success.

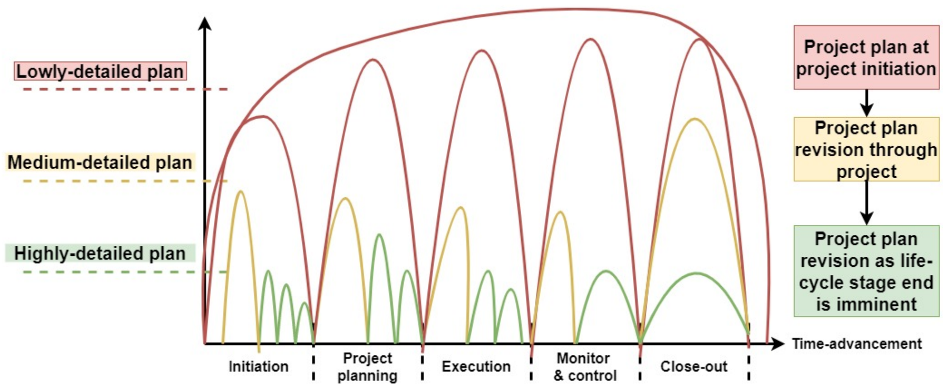


Figure 1: Rolling wave planning enables progressive elaboration of project plan

Accordingly, the project team's workflow has been tailored for "rolling-wave" planning in order to tackle unwanted emergences through iteration-based planning. As such, "rapid prototyping" with "rolling-wave" planning has enabled the project team to perform frontloading; starting with the process(es) that have higher chances of producing unwanted emergences e.g. system prototyping.

Furthermore, the global pandemic and chaos caused by SARS-CoV-2 (see [7]) has led to instability and shock in world economy and health. Our project progression has been halted by a degree unforeseen because of the stated pandemic, but iterational, rolling-wave planning has helped the group on a week-by-week basis to organize further project-work. See section 19 for more information. In addition to that, the project organization's structure (see section 3) and digital communication have been key in keeping the project alive. It has therefore been possible to keep the project somewhat on-track, despite the shockwave absorbed due to stated reason.

3 Project Organization and Infrastructure

3.1 External interfaces

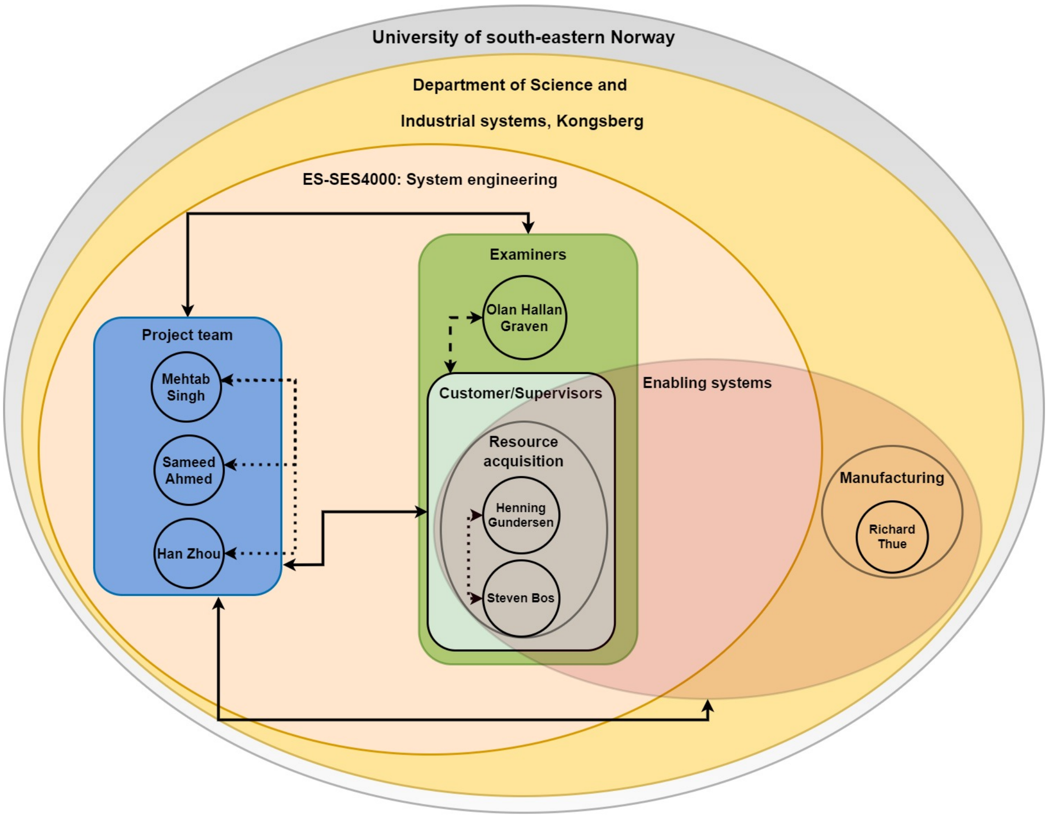


Figure 2: Entity-overlapping organizational structure of project-of-interest

See Fig. 2 for organizational relations building the fundament of project-of-interest's infrastructure. Project-of-interest is a part of compulsory coursework in "ES-SES4000: System eng." present in syllabus of course in "Systems engineering with Embedded systems". The course is conducted by "University of south-eastern Norway", specifically by the "Department of Science and Industrial systems, Kongsberg". Project supervisors are Henning Gundersen and Steven Bos, from whom project-of-interest was acquired.

Supervisors and institute leader Olaf Hallan Graven constitute the examiners that will set a grade on this project, its execution and completion. In addition to that, Richard Thue has contributed with manufacturing of project team's designed parts used in Nagini and thereby classifies as an "enabling system" in accordance with [8].

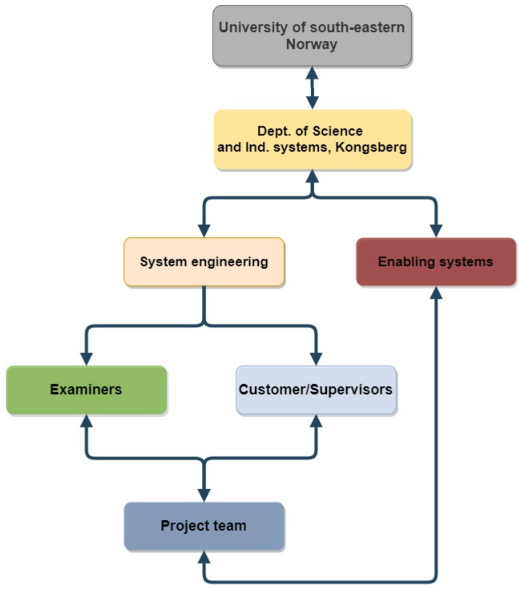


Figure 3: Hierarchical organizational structure of project-of-interest

Furthermore, a hierarchical organizational structure means that chain of command directs from top to bottom; bottom level carry out the work relayed by higher levels. The organizational structure of our project can be considered hierarchical(see [9] and [10] because of project team's inability to completely override commands from higher levels and due to project team's duty to carry out project given by supervisors. See Fig. 3 for reference. However, project team's performance contributes to the final decisions concluded by immediate higher levels, i.e examiners and supervisors. It is worth noting that the Dept. of Science and Industry systems are fundamentally responsible for providing the project as compulsory coursework, but also all enabling systems that are needed for stated coursework. Moreover, project-of-interest organization is structured with respect to thorough supervision of stated of given project. This has been reflected through project-lifecycle, as supervisors and project team has averagely had one weekly meeting during project-of-interest.

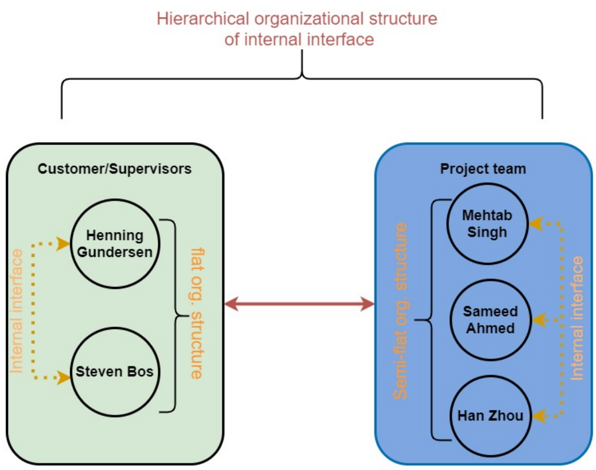


Figure 4: Relations and structure of internal interface

3.2 Internal interfaces

Members of project team interface internally through cooperative work and communication. The internal interface of project team can be regarded as semi-flat organization per [11]. As a matter of boundary definition, supervisors can be considered part of the internal interface while still being an external entity due to active supervision of project team. See Fig. 4 for reference. The overall internal interface is of hierarchical nature, with supervisors being higher level, as depicted in Fig. 3.

4 Project Scope Statement

Scope management for the Snake Robot Project is going to be the only responsibility of the Project Leader. The scope for this project is defined by the Scope Statement, and Work Breakdown Structure (WBS). The Project Leader, Supervisors, and Stakeholders will establish and approve documentation for measuring project scope which incorporates deliverable quality checklists and work performance measurements.

Proposed scope changes could also be initiated by the Project Leader, Stakeholders or any member of the project team. All change requests are going to be submitted to the Project Leader who will then evaluate the requested scope change. Upon acceptance of the scope change request, the Project Leader will submit the scope change request to the both Supervisors for acceptance. Upon approval of scope changes by the Supervisors, the Project Leader will update all project documents and communicate the scope change to all or any stakeholders.

The ultimate project scope and project deliverables will require the acceptance of the Supervisors and Supervisors will take the decision on supported feedback input from the stakeholders and Project leader.

The Project Sponsor is liable for formally accepting the project's final deliverable. This acceptance is going to be supported a review of all project documentation, testing results, beta trial results, and completion of all tasks/work packages and functionality.

5 Project context & NTCP analysis

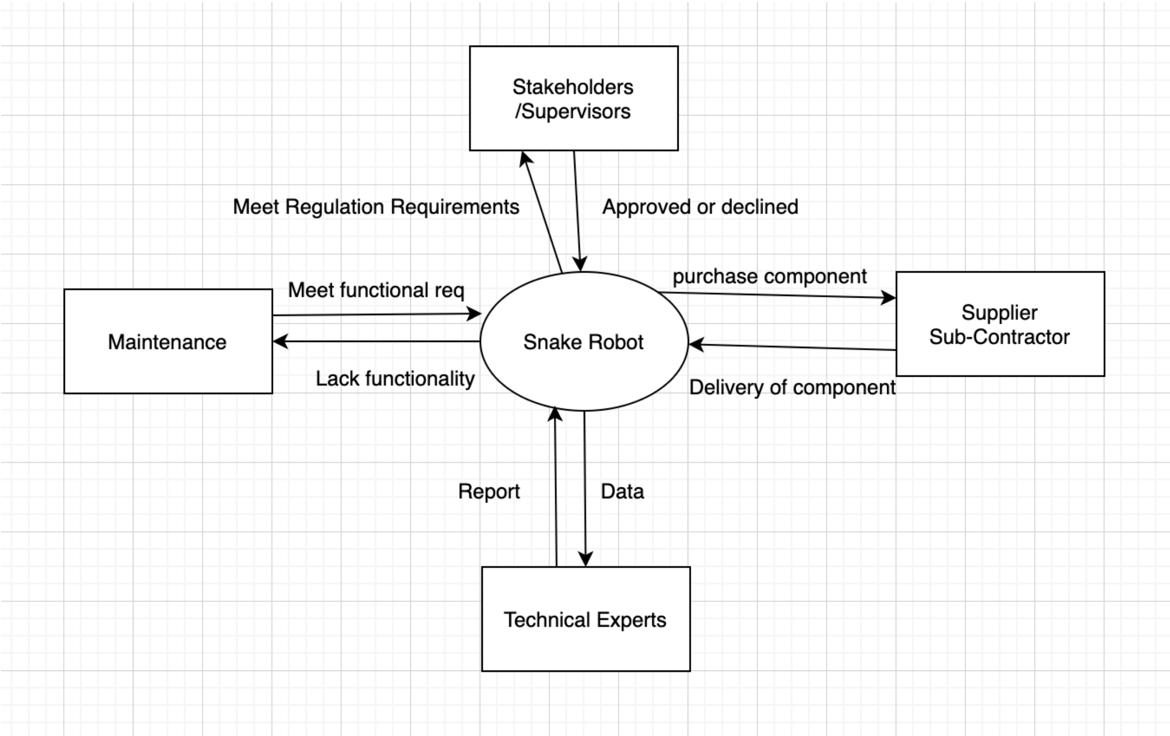


Figure 5: Project Context Diagram

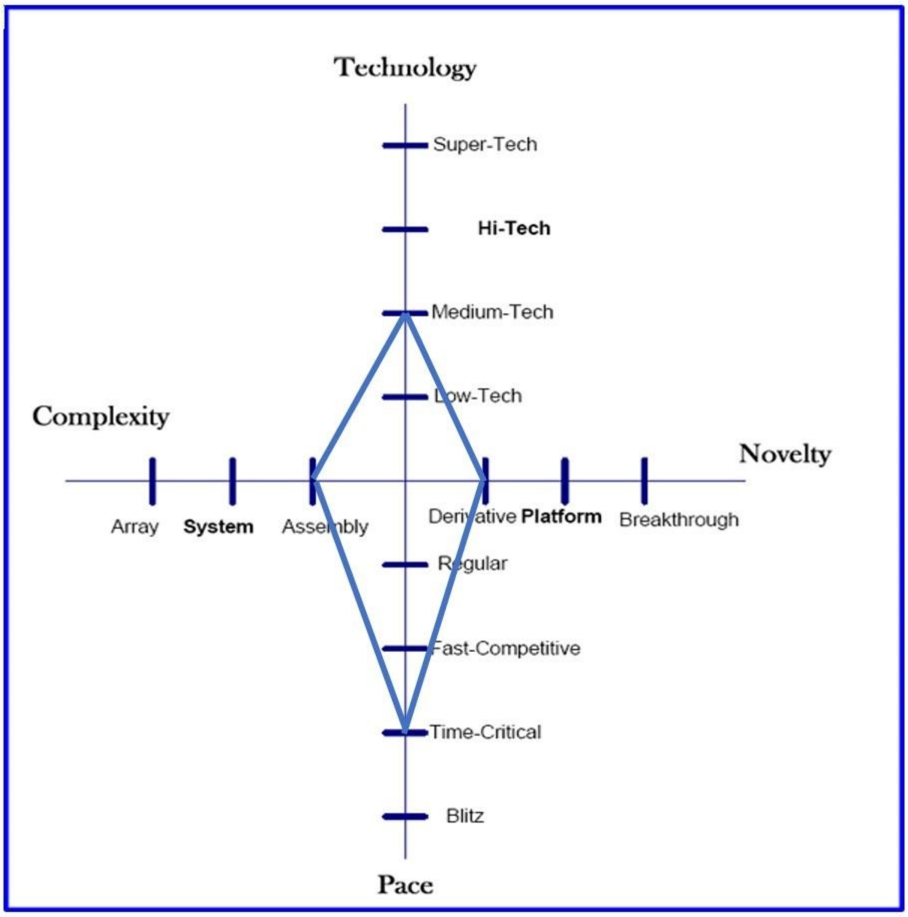


Figure 6: NTCP Diagram

NTCP diagram is illustrated in Fig. 6.

Novelty: This project is stated to build a robot to mimic the snake movements thus is a derivative of the robotic product.

Technology: this project is an assembly operation with known technology but there are some additional new features, therefore, it falls into Medium technology at the NTCP diagram below.

Complexity: This project involves three students and two supervisors from the USN, a limited scope from the stakeholder's perspective, thus is recognized as an assembly project.

Pace: Since there are only 15 weeks deployed to this project, even we can relax the time constraints to the ramification as regular, we still prefer to set the time scope at the branch of time-critical, according to NTCP modeling.

6 Project Success Factors

The project success is not just a business to the project managers and the leaders. It is a business to all stakeholder involved, even it is just a technical project. Because it is the humans creating the technique, it is the humans consuming and producing the technique efforts, e.g. draw.io for architecture drawing, Github platform and Arduino system. It is also the humans obsessing the project success, including the physical part of the system engineering project.

So the project success factor is a wide perspective, not only including the product, the project effectiveness, but also the stakeholders and team members. A project team with equally competence, the workload responsibilities combined with a time-critical project, require everyone effort. One member absent, even not a critical resource, can cause the trouble for a project success in the aspect of project planning or project resources redistribution. As such, the responsibility for a project success is relied on the stakeholders involved. Four our project, due to its scope, we will limit the discussion of the project success factor in two dimensions: the project effectiveness and the impact on the team.

6.1 Project effectiveness [12]

We adapted the fast prototype project model derived from Scrum and Alberto Sols model. We planned and did weekly review of the project progress against the objectives. We planned and used the work break down list for discussion.

The approach is expected to be relatively effective according to the schedule. There is empirical evidence that project can be easily failed. And a failed project may bear the future benefit to a new project. We considered the resources constraints, critical risks and the time frame with regards to the project success opportunities

6.2 Impact on the team [12]

The success factor on the team is expected that we get more first-hand knowledge on Github platform, Arduino system—IDE and Atmega board –we get to know each other in the team in terms of the communication. We all get a chance to try the role as a project leader. We all get withstand the project lifecycle.

7 Milestones and tollgates

Table 1: Milestone list

Major Milestones	Description	Date
Complete Requirements Gathering	All requirements for Snake Robot must be determined for design	2/20/2020
Design of Snake Robot	This is the theoretical design for the Hardware and software and its functionality	3/01/2020
Completion of Software and Hardware Phase of Snake Robot	Completion of coding resulting in software prototype. While Completion of assembly of hardware resulting in hardware prototype.	04/20/2020
Complete Snake Robot Debugging and Testing	All functionality is tested, and all identified errors corrected.	05/15/2020
Complete Transition of Snake Robot to Supervisors	Completed hardware and software and documentation transitioned to USN.	06/02/2020

Table 1 lists the main milestones for the Snake Robot Project. This table is included only of main and important project milestones such as toll gate review or completion of a different project phase. There may be smaller milestones which are not part of this table but are included in the work breakdown structure and project schedule. If there are any preparation delays which may impact a milestone or delivery date, the project leader must be notified immediately so proactive measures may be taken to mitigate slides in dates. The responsibility of the project leader also includes communicating any changes to the milestone which has been approved or change in date to the project team.

8 Project Schedule Management

The Snake Robot Project would require all project team members for the whole duration of the project although levels of effort will vary when the project progresses. The Project is scheduled to last Four Months with a standard 40-hour work weeks.

Table 2: Schedule Plan

Project Phase	Time Duration	Comments
Planning	Four Weeks	Includes work hours for all project team members for gathering requirements and planning project
Design	Two weeks	Includes work hours for all project team members for work on Snake Robot conceptual design
Coding/Hardware assembly	Three Weeks	Includes all work hours for coding and hardware assembly of Robot.
Integration and Testing	Four Weeks	Includes all work hours for integration and testing (including beta testing) of Snake Robot
Transition and Closeout	Two Weeks	Includes all work hours for transition to operations and project closeout

9 Management plan: Modifications Handling

There are some standard protocols which must be followed in order to make changes in the project during the development stage of the Snake Robot. The important stages which are mandatory to follow to make changes in the project are list below.

Stage 1:
In the first stage main aim is to identify the need for a change (Asked by any Stakeholder/Supervisors). In order to file change, the requestor will submit a change request to the project leader to make changes.

Stage 2:
The second stage is recording a change in the change request register (done by Project leader). In order to trace every change to the project during development, the project leader will retain a log of all change requests for the period of the project in the form of change request register.

Stage 3:
At the third stage, the mechanism is to Conduct an assessment of the change (Project Team, Project Leader, Requestor). To assess the impact of change on risk, scope, cost and schedule the project leader will conduct an evaluation.

Stage 4:
Submit a change request to the Supervisors (Done by Project leader) The project leader will submit the analysis and alter request to the supervisors for review.

Stage 5:
The Supervisors will discuss the proposed change and choose whether or not it'll be approved all submitted information or reject and ask to resubmit with a new draft.

Stage 6:
Implement change (Responsibility of Project Leader). If a change is approved by the Supervisors/Stakeholders, the project leader will update and re-baseline project documentation as necessary, also ensures that any changes are communicated to the project team and stakeholders.

Overall summary of the above standard protocol for modifications is; Any team member or stakeholder may submit a change request for the Snake Robot Project. The Snake Robot Project Sponsor (Both Supervisors in our case) will chair the Change meeting and any changes to project scope, cost, or schedule must meet their approval. The project leader will be going to log all the changes within the change control register and also keep the track of changes whether those changes have been approved or not.

10 Management plan: Communications

Table 3: Management Plan

Communication Type	Description	Frequency	Format	Participants/ Distribution	Deliverable	Owner
Weekly Status Report	Email summary of project status	Weekly	Email	Project Sponsor and Team	Status Report	Project Leader
Weekly Project Team Meeting	Meeting to review action register and status	Once a Week	In Person	Project Sponsor and Team	Updated Action Register	Project Leader
Project Monthly Review (PMR)	Present metrics and status to team and sponsor	Every Month	In Person	Project Sponsor and Team	Status and Metric Presentation	Project Leader
Project Gate Reviews	Present closeout of project phases and kickoff next phase	As Needed	In Person	Project Sponsor and Team	Phase completion report and phase kickoff	Project Leader
Technical Design Review	Review of any technical designs or work associated with the project	As Needed	In Person	Project Team	Technical Design Package	Project Leader

The plan in table 3 for communications management sets the communications framework for this project. It will function as a guide for communications throughout the lifetime of the project and can be updated as communication requirements change. This plan identifies and defines the roles of Snake Robot project team members as they pertain to communications. This plan also has communication conduct for meetings and communication requirements of this project and other sorts of communication. The contact information is also included of all the stakeholders which are directly involved within the project

10.1 Contact Information

Table 4: Contact information

Name	Title	E-mail	Cell Phone
Henning Gundersen	Project Sponsor Supervisor	henning.gundersen@usn.no	
Steven Bos	Project Sponsor Supervisor	steven.bos@usn.no	
Sameed Ahmed	Programmer Technical Writer	230708@student.usn.no	
Mehtab Singh	Senior Programmer Hardware Engineer Technical Writer	140411@student.usn.no	+47 46361717
Han Zhou	Document Controller Technical Writer	228624@student.usn.no	

10.2 Communications Conduct

10.2.1 Meetings

Team Meeting

Date | time [Date | time] | *Location* [Location]

Meeting called by	[Meeting called by]	Attendees [Attendees]
Type of meeting	[Type of meeting]	Please read [Please read]
Facilitator	[Facilitator]	Please bring [Please bring]
Note taker	[Note taker]	
Timekeeper	[Timekeeper]	

Agenda Items

Topic	Presenter	Time allotted
☐ [Topic]	[Presenter]	[Time]
☐ [Topic]	[Presenter]	[Time]
☐ [Topic]	[Presenter]	[Time]
☐ [Topic]	[Presenter]	[Time]
☐ [Topic]	[Presenter]	[Time]
☐ [Topic]	[Presenter]	[Time]
☐ [Topic]	[Presenter]	[Time]

Other Information

Observers [Observers]
Resources [Resources]
Special notes [Special notes]

Figure 7: Template for meeting agenda

The Project Leader will distribute a meeting agenda given below at least 1 day prior to any scheduled meeting and all participants are expected to review the agenda prior to the meeting. The template for meeting agendas is given below in Fig. 7, which will be used throughout the duration of the project. During meetings, the responsibility of the timekeeper is to make sure that the agenda of the meeting is addressed within the time allocated and the group adheres to it. The Notes for the meeting are taken by the Notes taker shown below in the template for distribution to the project team upon completion of the project meeting. In every meeting, it will be ensured by the meeting chairperson that conversation should not drift from the actual meeting agenda otherwise it can be wastage of time and resources. It is mandatory for all participants to arrive at each group meeting on time and all mobile devices should turn off before the start of every meeting and remain turned off till the end of the meeting to avoid distractions. The meeting minutes of each meeting will be sent out to every group member no later than 12 hours after the completion of each meeting. The meeting minutes template is also given below which has been used throughout the project in Fig. 8.

Team Meeting

Date
Time
Location

Meeting called by:	Enter meeting organizer here	**Type of meeting:**	Enter meeting type here
Facilitator:	Enter meeting facilitator here	**Note taker:**	Enter note taker here
Timekeeper:	Enter meeting timekeeper here		

Attendees: Enter attendees here

Please read: Enter reading list here

Please bring: Enter items to bring here

Minutes

Agenda item: Enter agenda item here **Presenter:** Enter presenter here

Discussion:

To get started right away, just tap any placeholder text (such as this) and start typing to replace it with your own.

Conclusions:

Enter conclusions here.

Action items	**Person responsible**	**Deadline**
✓ Enter action items here	Enter person responsible here	Enter deadline here
✓ Enter action items here	Enter person responsible here	Enter deadline here
✓ Enter action items here	Enter person responsible here	Enter deadline here

Figure 8: Meeting Minutes Template

10.2.2 Email

All email related to the Snake Robot Project should be professional, free of errors, and provide brief communication. The communication matrix above can be used to send the emails to the correct participants of the project. The standard organizational suite program should be used for all attachments of the project and stick to established company formats. The different issues can be put forward through email and when sending email, a person should provide a brief background on the issue, it should discuss what the issue is and provide a proper form of recommendation on how to rectify the issue. The Project Leader should be included on any email pertaining to the Snake Robot Project.

10.2.3 Informal Communications

While informal communication is a part of every project in the Academic institutes, industry and is very important for successful project completion, concerns, or any issues or updates that arise from informal discussion between team members must be addressed by the project leader and strict action must be taken to improve the situation

11 Cost Plan

The Project leader is going to be responsible for managing and reporting on the project's cost throughout the duration of the project. The Project Leader will present and review the project's cost performance during the weekly project status meeting. The project leader is responsible to calculate the cost deviation and put forward the option to the project sponsors (Supervisors) how to put project back on budget, earned value calculations can be used for this purpose. Snake Robot project sponsors (Both Supervisors in our case) are responsible for all the budget authority and decisions and to incorporate budges changes.

Cost and Schedule Performance are going to be reported on a monthly basis by the Earned value calculations are going to be compiled by the Project Leader and reported at the weekly project status meeting. In case of any abnormality in term of values and concerns that values will reach or approach critical stage before the next meeting, the project sponsor (Supervisors) will be informed about this situation through the project leader.

12 Management plan: Procurement

All the procurement activities will be handles by the Project Leader under this project. The Project Manager is permitted for the approval of all procurement actions up to NOK 500. Any procurement actions exceeding the amount above must be approved and signed by the Project Supervisors

This project overall requires minimal procurements, but in the situation where procurement is needed, the project team will deliberately work with the current project Leader to identify all services and items needed to be procured in order for the successful completion of this project. In the event a purchase becomes necessary, the Project Leader is going to be liable for managing any selected vendor or external resource. The Project Leader also will measure performance because it relates to the seller providing necessary goods and/or services and communicates this to the project supervisors.

13 Management plan: Risk Handling

The approach for managing risks for the Snake Robot Project includes a methodical process by which the project team identifies, scores, and ranks the varied risks. Every effort is going to be made to proactively identify risks before time so as to implement a mitigation strategy from the project's onset. the foremost likely and highest impact risks were added to the project schedule to make sure that the assigned risk managers take the required steps to implement the mitigation response at the acceptable time during the schedule. Risk managers will provide status updates on their assigned risks within the weekly project team meetings, but only the meetings include their risk's planned timeframe.

Upon the completion of the project, during the closing process, the project Leader will analyze each risk also because of the risk management process. Supported this analysis, the project Leader will identify any improvements which will be made to the danger management process for future projects. These improvements are going to be captured as a part of the teachings learned knowledge domain.

14 Timeline for Resources

14.1 Resources

Even we adapted a fast prototype project life cycle, we still need to fill the time requirement of 17 weeks with three people. The three team members have variate software skills on programming language, platform and other related knowledge. So the project lifecycle is divided into three major phases, the hardware development phase at the first 5 weeks, the software development phase at precedent 5 weeks, then the final 7 weeks for integration and documentation work tasks.

During the 17 weeks, there is a writing assignment which is not related to the project, but due in the late Mars. In the middle of May, there is an exam which is not related to the project. That means that we don't have a fulltime 17 weeks in reality. And the weight of time resources cannot be evenly scheduled through the project life cycle. Table 5 listed the basic resources required for this project.

Table 5: Resource list

Phase	Resources	Notes
Hardware	Hardware developer	
Hardware	Team members	
Hardware	3D printer	
Software	System designer	
Software	Arduino kit	
All three phases	computers	
Software	Software developer	
All three phases	Project manager	
Final stage	Document controller	

14.2 Planning GANTT

GANTT is invented by Henry L. Gantt in 1903, for managing tasks, resources and activities. The chart organized the tasks system focused on timeline. In the chart, in the horizontal axis represents the timescale and the timeline resources, while the vertical axis represents the allocation of timeline resources at each time frame. [13]

We adapted GANTT chart for the master plan and the final weeks plan. The timeline resources have been extracted in the final weeks plan to catch up the detailed resource consumption.

For the final weeks, we developed the plan week by week. The example from week 12 will be look like Fig. 9.

	Charpter	task description	responsibil	planed time	4/27	4/28	4/29	4/30	5/15
PMP	1	Project Description	Sameed	1Hrs/1page(or More	complete				1 page
PMP	2	Project Management Approach	Singh	3Hrs/2Pages(or More)			start		
PMP	3	Project Organization	Singh	2Hrs/2Pages(or More)			start		
PMP	4	Project Scope Statement	Sameed	2Hrs/2Pages(or Mor	complete				1 page
PMP	5	Project Context Diagram and NTCP Analysis	Sameed	3Hrs/2Pages(or Mor	complete				1 page
PMP	6	Project Success Factors	Han	6Hrs/3Pages(or More)		start		%complete	11/2 page
PMP	7	Milestones and tollgates	Sameed	1Hrs/2Pages(or Mor	complete				1 page
PMP	8	Project Schedule management	Sameed	3Hrs/2Pages(or Mor	60%			complete?	1 page
PMP	9	Management Plan for Modifications	Sameed	2Hrs/1Pages(or Mor	90%			complete?	2 pages
PMP	10	Management Plan for Communications	Sameed	5Hrs/4Pages(or Mor	complete				5 pages
PMP	11	Cost Management Plan	Sameed	2Hrs/2Pages(or Mor	20%			complete	1 page
PMP	12	Management Plan for Procurement	Sameed	2Hrs/1Pages(or Mor	20%			complete	1 page
PMP	13	Management Plan for Risk Handling	Sameed	2Hrs/1Pages(or Mor	20%			complete	1 page
PMP	14	Timeline for Resources	Han	5Hrs/2Pages(or More)				start	50%
PMP	15	Environment, infrastructure, security, and safety plan	Singh	3Hrs/1Pages(or More)			???		
PMP	16	Approach for technical and management review and reporting to s	Han	5Hrs/2Pages (or More)		start		complete?	50%

Figure 9: Week 12 work break down

The advantages of GANTT chart is that

- The easiness to catch the primary tasks and the scope of the project
- The visualizing of the tasks and resources planning in a timeline.
- The directness for a quickly planning

The disadvantages of GANTT chart is that

- The precedence tasks presented in the chart may not have the actual dependency as showed
- Compare to PERT, there is no indication in the GANTT chart of float or slack effect.
- It is not necessarily easy to see the resource consumption progress in a GANTT chart
- It is difficult to compare directly of the planned activities and the actual activities

14.3 Critical concern

Critical chain focuses also on tasks dependencies and resources. [14] The critical path for our project is relied on the scope out of our prototype. One is the coronavirus pandemic caused the shutdown of the school, which escalated the difficulty for the group to communicate and to make prototype together. Another is the resource allocation conflict at the beginning of the May. There was an exam at the same period when the project was planned to the integration and testing phase. To handle this critical chain, we set the rest time resources after the hardware develop and the software develop into a direct final path, which combine the final stage of the prototype testing, the documentation writing and the presentation preparation in one component.

In another scenario, if the software personal had emergency that he would be unavailable, the critical situation will set the project to hold. This impediment to the project progress will be severe, when the resources we have is of scarcity.

As such, an incremental approach in the Scrum model, will benefit our project management in handling the critical chain.

15 Resource acquisition

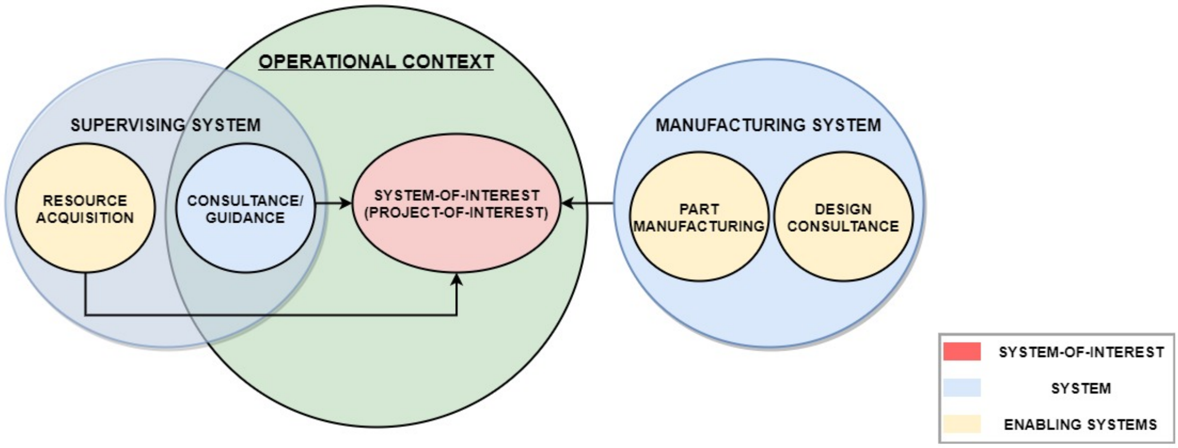


Figure 10: Operational context diagram showing project-of-interest and supporting systems

See Fig. 10 for reference; in project-of-interest's operational context, system-of-interest is project-of-interest. Otherwise, system-of-interest is developed product. As depicted, the supervising system consisting of supervisors Henning Gundersen and Steven Bos function as a resource acquisition subsystem and guidance subsystem for the life cycle duration of project-of-interest. Electronic components that are used in system-of-interest (i.e. Nagini) have been supplied by resource acquisition subsystem.

Accordingly, when project team has been in need of electronic components or other resources such as plywood for laser-cut parts (part-manufacturing), resource acquisition entity has supplied stated resources or pointed to other entities within or outside of project-of-interest's context limits that can supply needed resources. See Fig. 2 for the contextual limits of project-of-interest. The subsystem has also communicated a regulation which refunds project team for resources that are acquired by private funds, outside of project-of-interest's context. However, a statement proving reasonable purchase context and receipt has to be presented in order for a valid refund. For acquisition of velcro and other equipment that has been needed for system-of-interest development or otherwise and has not been supplied by resource acquisition, private funds have been spent.

In addition to that, obtaining manufactured parts from manufacturing system depicted in Fig. 2 is also a form of resource acquisition despite the fact that it is acquisition of resources designed by project team. Furthermore, difficulty in resource acquisition arose for some time due to the sudden pandemic outbreak of SARS-CoV-2. During this period, resource acquisition subsystem was still functioning by delivering requested, necessary parts through post mail. Retrieving manufactured parts from manufacturing system continued as normal. This enabled progress of project-of-interest which would otherwise have been halted to a further degree.

16 Technical & Management Approach

According to the "Collapsed" Vee model [13], the communication with the stakeholders shall be much more in the initial project phase, and then go into a decremented frequency which mainly in agreed regular reporting process. The management of the review and reporting to the stakeholders is prepared weekly. The develop and delivery of the prototype is also planned in a weekly basis. The process flow is showed in Fig. 11.

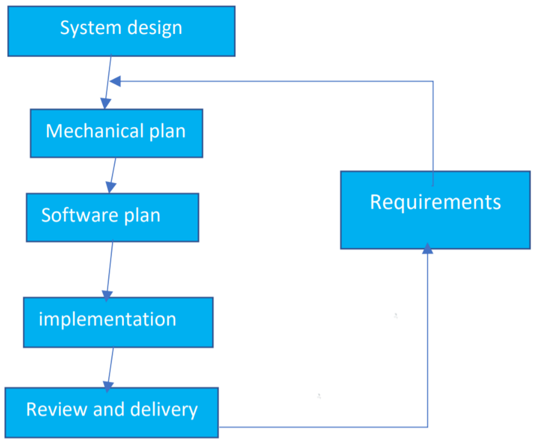


Figure 11: Technical management flow

We will adapt ISO15288 [15] technical management elements as the standard for the review and reporting. Incremental delivery of code developing, and functional developing is derived. We have stages to build up a functional robot when the requirement is changing.

The incremental approach we planned to use is not the traditional increment model, in which each increment is fixed in the frame. Because the feature of the software system, the new component from the next section may affect the predecessor in the project lifecycle. Thus, we chose to a prototype system architecture plan in a form of incremental component. The short develop and delivery duration is the advantage for the increment component. The environment change, both inside and outside the scope of the project interest, will not be a critical impact to the incremental plan. And the flexible incremental plan can solve and absorbed the change into expected project path. If the hardware is not done in time, the software component can continue be developed and delivered for review. Since our project is to develop a prototype, the functional milestones are according to the ISO15289 [16] standard.

17 Toolkit for prototyping

System-of-interest, from perspective of hardware, is built of lego, custom-made parts and easy obtainable electronics components. The custom-made parts have been designed by project team and 3D printed by using the manufacturing system depicted in Fig. 2. Most custom-made parts and electronic components have been modeled by hand, and if necessary via software to enable 3D printing. The hand-modeled construction plan of Nagini v.01 is available in Appendix A in [1]. A list of total equipment (with downloadable links for 3D print-files) is available in Appendix B in [1].

17.1 Manufacturing of parts and components

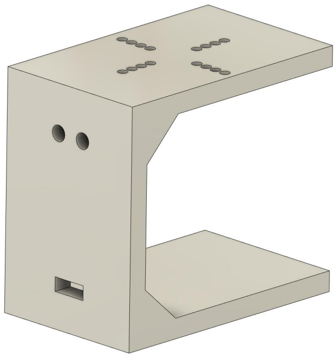
17.1.1 Hand-modeling

Initial parts (such as the link, see Fig. 12.1) of system-of-interest, as stated, were first hand-modeled with dimensions (see p.2 and p.2A of Appendix A in [1]) that fit other electronic components that needed to be housed (such as the servo motor). Hand-modeling of components and parts were done on white paper with ruler, digital slide ruler and pencil. Precision in measurement down to millimeter standards were followed, in which the initial 3D printed link was a success in terms of intended dimensions and thus functionality.

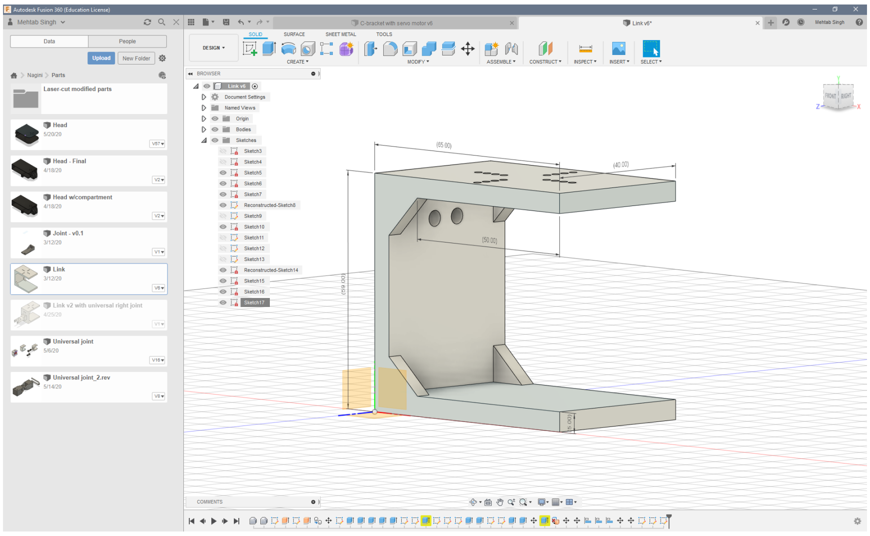
As depicted in Fig. 3.4, p.118 in [17], it is the translation of system requirements that gives rise to the system architecture. Since the project group chose hardware based on system functionality early on in the life-cycle of project-of-interest, the hand-modeling of these components and parts were one of the initial design-related tasks.

17.1.2 3D-modeling: AutoDesk Fusion360

In order to 3D print parts for prototyping, the project team has used AutoDesk Fusion360; a "cloud-based 3D CAD/CAM software" for modeling and preparation of parts for 3D printing. Project team designed custom parts and sent the necessary production files to Richard Thue of manufacturing system in order to 3D print needed parts using printers belonging to University of South-Eastern Norway, Kongsberg. In addition to that, Richard Thue has also aided with design consultance by communicating when sent designs were non-optimal for 3D printing. This enabled an iterative design process of all printed parts; a core concept of Systems Engineering as a discipline.



12.1: A link modeled in Fusion360



12.2: Autodesk Fusion360 designspace

Figure 12: Autodesk Fusion360 enables manufacturing of custom-designed parts

17.1.3 Tools and equipment for assembly

A small number of different tools have been used to assemble system-of-interest. See Appendix B in [1] for reference. In order to mount servo motors to links, two M3 flathead woodscrews have been utilized with a PH 1x75mm screwdriver secure them. To secure the joint between two links, the same screwdriver with two M4 pan head machine screw has been used. See Fig. 14.

Moreover, a glue gun has been utilized to attach lego technic beams and joints to the link. Glue has also been used to attach the face onto the head. In addition to that, a cable sleeve with 12mm diameter is used for better cable management and routing. Velcro, or double-sided tape has been used to attach electronic components to system-of-interest.

Figure 13: PH 1x75mm screwdriver

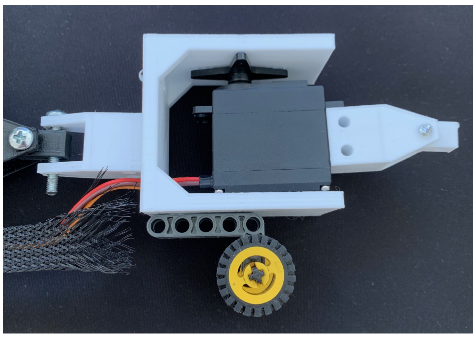


Figure 14: Link with mounted servo motor and attached joint and lego technic beam

17.2 Programming of system-of-interest

At the heart of system-of-interest's behaviour lies a microcontroller; Arduino 2560. See [18] for further information on this component. The microcontroller acts as a brain for the system-of-interest and controls all connected hardware through its GPIO (general purpose input/output) pins. In order to program the Arduino, the Arduino IDE (integrated development environment) has been used. See [19] for more information. The behavioural aspect of programmed software is further described in section 3.3 of [1]. Utilized programming language is a combination of C and C++. For more information on the build process of programmed software on a Arduino, see [20], and [21] for other frequently asked questions.

18 Validation and Verification

Since the group decision is that there is no customer or user or contractor for this project, the group is agreed to use a Fast Prototype modeling derived from the Alberto system engineering modeling, the validation and verification section will be ignored.

However, it is expected the testing processing will be long according to general understanding of system engineering principal. The testing and simulation activities may even be arduous, as the performance requirement is absence.

19 Environment, safety & health: SARS-CoV-2 implications

Due to the worldwide, pandemic outbreak of COVID-19 disease caused by SARS-CoV-2 virus, world health has taken a tremendous blow. As of 02:20 AM (CEST/GMT+2) 28/05/2020, 5.781.650 cases (per [22]) of COVID-19 have been confirmed worldwide. Total 356.839 lives are lost due to the disease and there are 52.971 lives still at critical stake. On the other hand, 2,493,347 people are stated recovered and there are hundreds of vaccines in development to battle this disease. See [23] for more information about initial outbreak and [7] for further information on corona virus.

Moreover, the world is in state of shock with millions of innocent lives lost over such short period of time. It is in no way an understatement to say that the remaining, existent world population is beyond gifted to still be alive. Countries that have been more fortunate with less death tolls compared to many countries and quicker control over the scatter of COVID-19, such as Norway, have started to slowly reinforce the daily, usual life of its citizens within reason, while respecting hazard regulations related to stated disease. This means a national, gradual and safe transition to how things were before the outbreak. However, the footprint of COVID-19 is so fatal that it has left thousands businesses out-of-commission, and thus many Norwegian citizens unemployed. It has also affected schools and national education, in addition to other parts of national infrastructure.

Naturally, project-of-interest has been impeded by COVID-19 as all other priorities, national or otherwise, were abruptly set aside in favor of increased health priority. This means that project-work at campuses were stopped, in fact campuses were closed off for all public and recommended way of communication was digital as the country was quarantined. The progress of project-of-interest took a toll; halted progress, higher uncertainty, risk in project-planning, non-optimal way of communication. Even though project-of-interest continued, carrying out project-work in quarantine was not even close to as efficient as in-person group meetings and working together with team mates at campus. Abruptly adapting to a new routine while constantly fearing for own and dear one's lives contributed to the sudden progress halt.

Per [24] and [25], depression and anxiety is heightened on a national level in Norway due to COVID-19. This is why it is even more important to take as much care of personal health; everything else is replaceable but not lives.

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