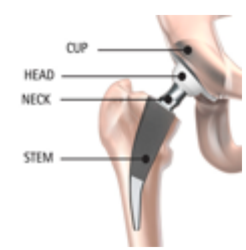
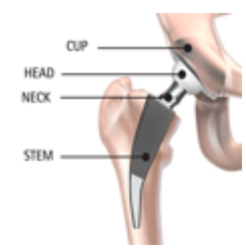
Robone: Next Generation Orthopedic Surgical Device

Andrew Hundt
Alex Strickland
Shahriar Sefati
Peter Kazanzides (Mentor)
Russell Taylor (Mentor)



Project Goal

Develop a prototype integrating several subsystems of a next generation robot for orthopedic surgery

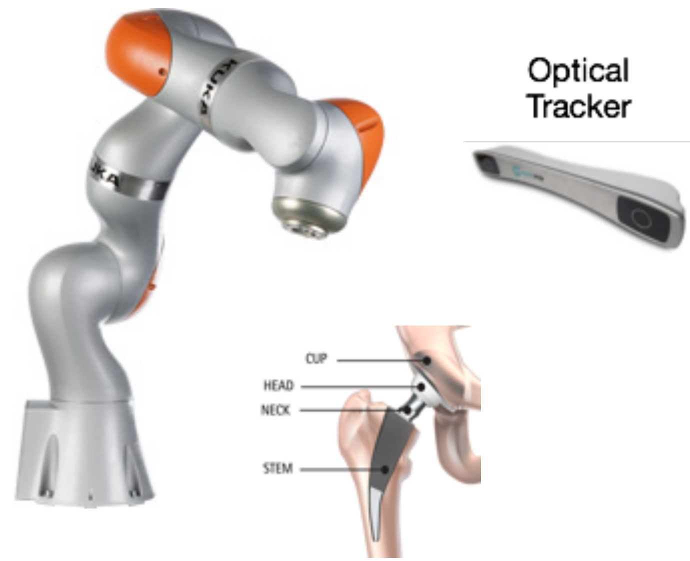


Project Relevance

The existing device isn't perfect and requires the patient to be fixed to the operating table, an invasive and time consuming process.

A next generation system will make real time position adjustments using a device such as an optical tracker so fixation is no longer necessary.

The goal is to enable faster and less invasive surgery with this type of computer assisted tool.



Technical Summary of Approach

The following slides will outline a technical summary of our approach.

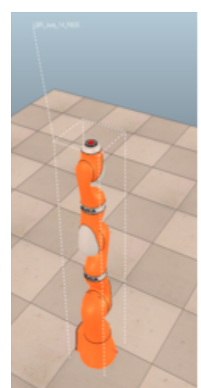
Please note that the numbers in brackets [0] indicate our time estimate for the task in “Ideal Full Time Equivalent Days”.

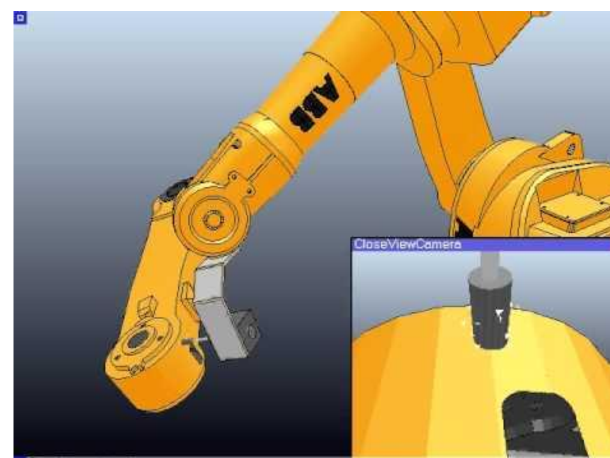
min goal

Initial Simulation

Create a simulation of the system in VREP without optical tracker

- Add arm to simulation [0]
- Integrate motion planning,
  - Most likely implemented using the reflexxess type II or type IV planning library. [2]
- Add milling simulation of simple object [2]
- Milling simulation of bone shaped object (may move) [2]
- Add simulation with optical tracker. (may go in step 5) [5]

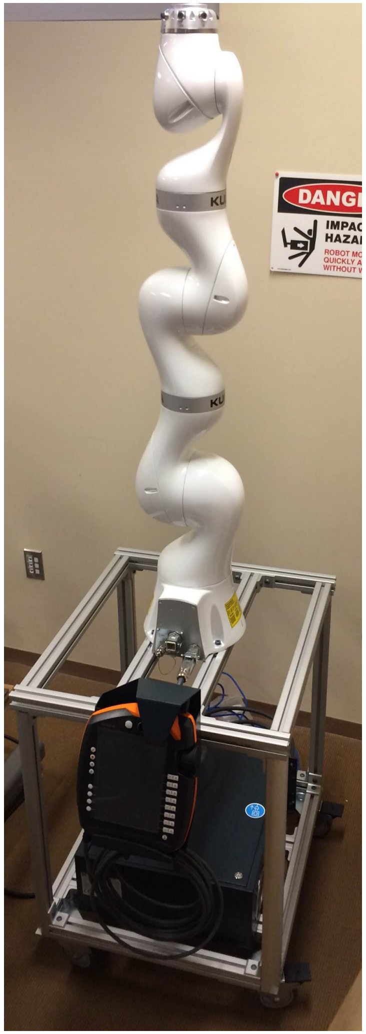




min goal

Initial Arm Integration

- Implement basic Java setup on Sunrise Connectivity suite. [2]
- Implement and test read arm state over Fast Robot Interface (FRI). [3]
- Implement and test commanding arm motion over FRI. [2]
- Collaborate with other kuka groups, if possible on path planning. [3]
- Move along simple series of points (joint and/or cartesian space) [5]

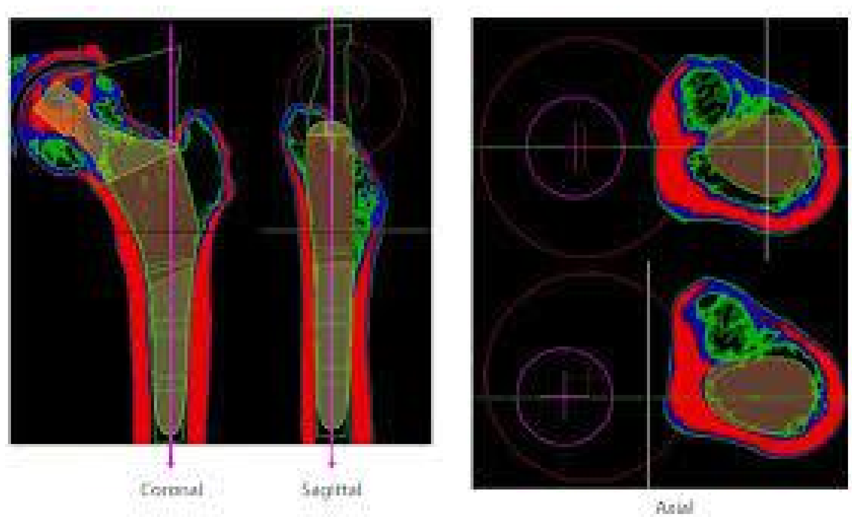


expected goal

Cut file Integration

Cut files specify the path the milling bit should follow to mill the implant shape from bone.

- Acquire ascii cut files [0.5]
- Implement ascii parsing and conversion to format amenable to sending to planner or arm as commands. [4]
- Test parsing and motion commands in simulation [2]
- Test parsing and motion commands on physical robot [2]



expected goal

Optical Tracker Integration

- Acquire optical tracker [0.5]
- Setup of optical tracker with kuka [1]
- Implement reading of optical tracker data into software, using existing saw components [3]
- Integrate optical tracking data into cut file and arm commanding loops [5]
- Reaction time testing [5]
    - draw a straight line on an object, move object and check response time
    - see “physical simulation of cutting” idea below
    - Characterize response time?
    - Improve response time if necessary

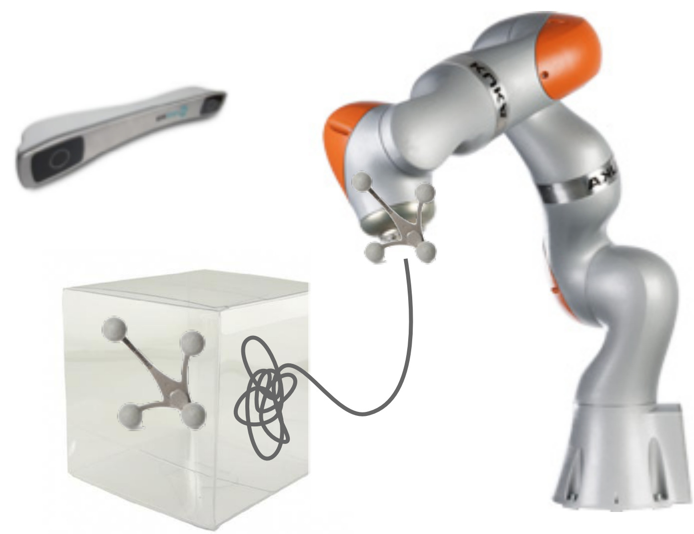
max goal

Milling Physical Simulation

Create a physical simulation of cutting, as opposed to a computer simulation.

The initial concept is to put an optical tracker fiducial on the end effector and have a clear box to simulate “bone”. We can then use the optical tracker to generate a simulated estimate of actual cutting. This avoids the complexity of acquiring materials to cut and dealing with the dust created by milling foam, wood or other test cutting materials.

- Design and Create fiducial mounting attachment [5]
- Implement logging of physical simulation [5]
- Integrate logging with VREP to visualize execution of simulation [5]
- Implement method to evaluate planned vs actual path within error bounds of sensors. [5]
- Create evaluation analysis [2]



max goal

Milling integration

Install physical milling equipment on arm and demonstrate real output shape cut from a demo material such as wood.

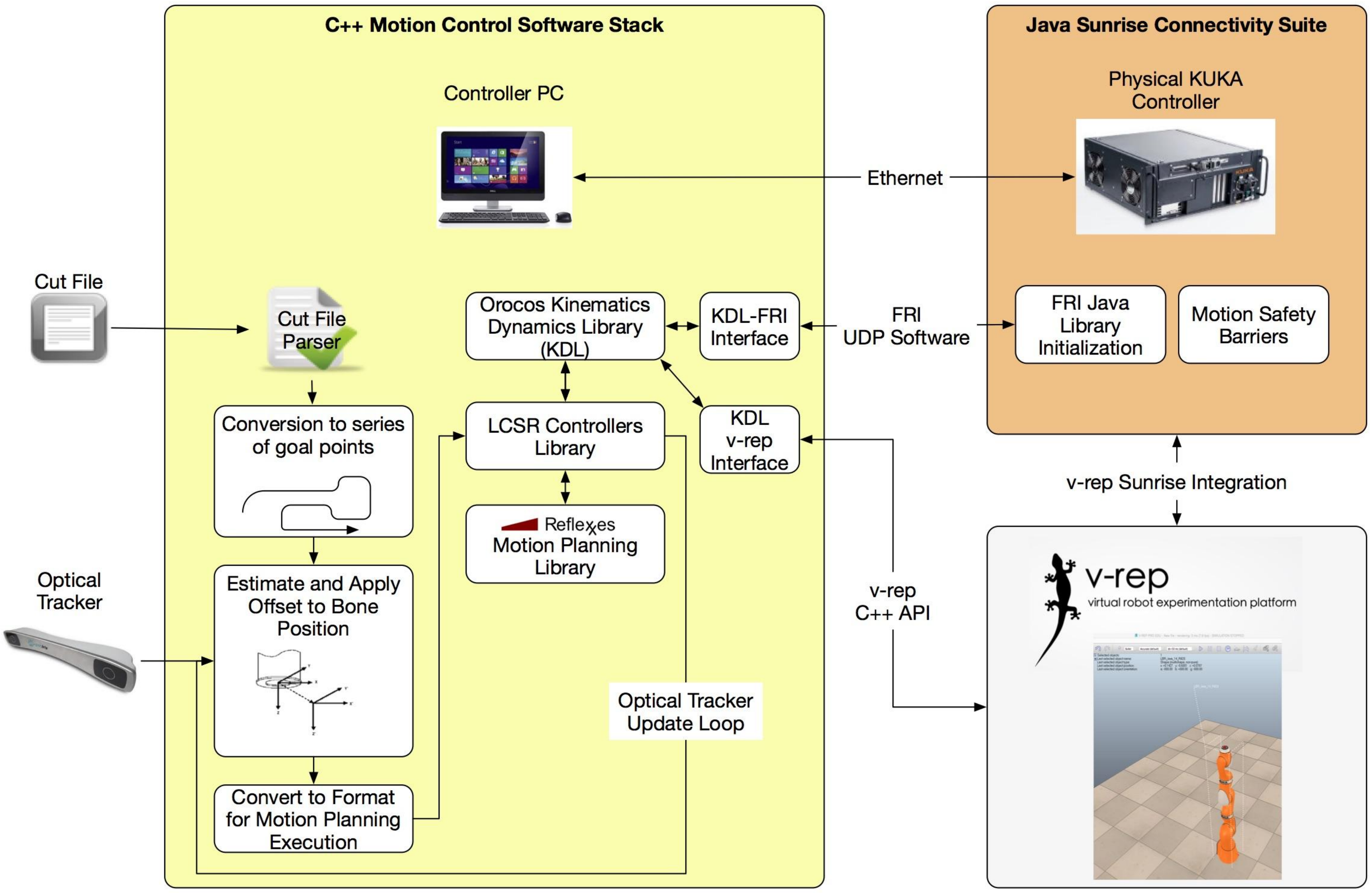
- Create or acquire milling attachment (or whatever other mechanism we will use) [5-10]
- [Many steps may be here for design and fabrication] [unknown]
- Test milling attachment [3]
  - If needed, find a machine shop on campus which is properly equipped to handle dust [1] (may take weeks of wall time)
- Integrate control of milling attachment with rest of system [5]

max goal

Investigate arm motion planning

- Minimize elbow movement during cutting scenario [unknown]
- Adjust cutting speed based on torque resistance of cutting [unknown]
- Investigate response and pre planning to avoid going beyond joint configuration limits. Consider stopping in real time and asking user to move bone and arm to a new position within the workspace. [unknown]
- Response to human touch, stopping path, following human pressure, and then resuming motion when human moves it approximately back on path. [unknown]

Initial Software Design Concept



Deliverables

Min

- Receive arm state in real time
- Read in cut file specifying shape of implant
- Drive both simulated and physical KUKA arm along cut file path

Expected

- Receive optical tracker position in real time and adjust cut path accordingly to maintain consistent final cut volume to the extent possible, considering algorithm latency and arm speed limits.
- Characterize performance

Max

- Allow human adjustment of elbow or removal of arm during motion
- Milling Integration
- Improve motion planning to minimize elbow movement
- Evaluate configuration and joint limits, especially if object cut path exits workspace of arm

Dependencies

Optical Tracker

- Acquisition of Device
- Integration with arm software and controller

Milling

- Access to space and materials for milling
- Creation or acquisition of actual milling device
- Integration of milling device into arm

Software

- Some higher quality level integration of arm control software, such as real time torque control, depends on planned software updates by the manufacturer, KUKA.

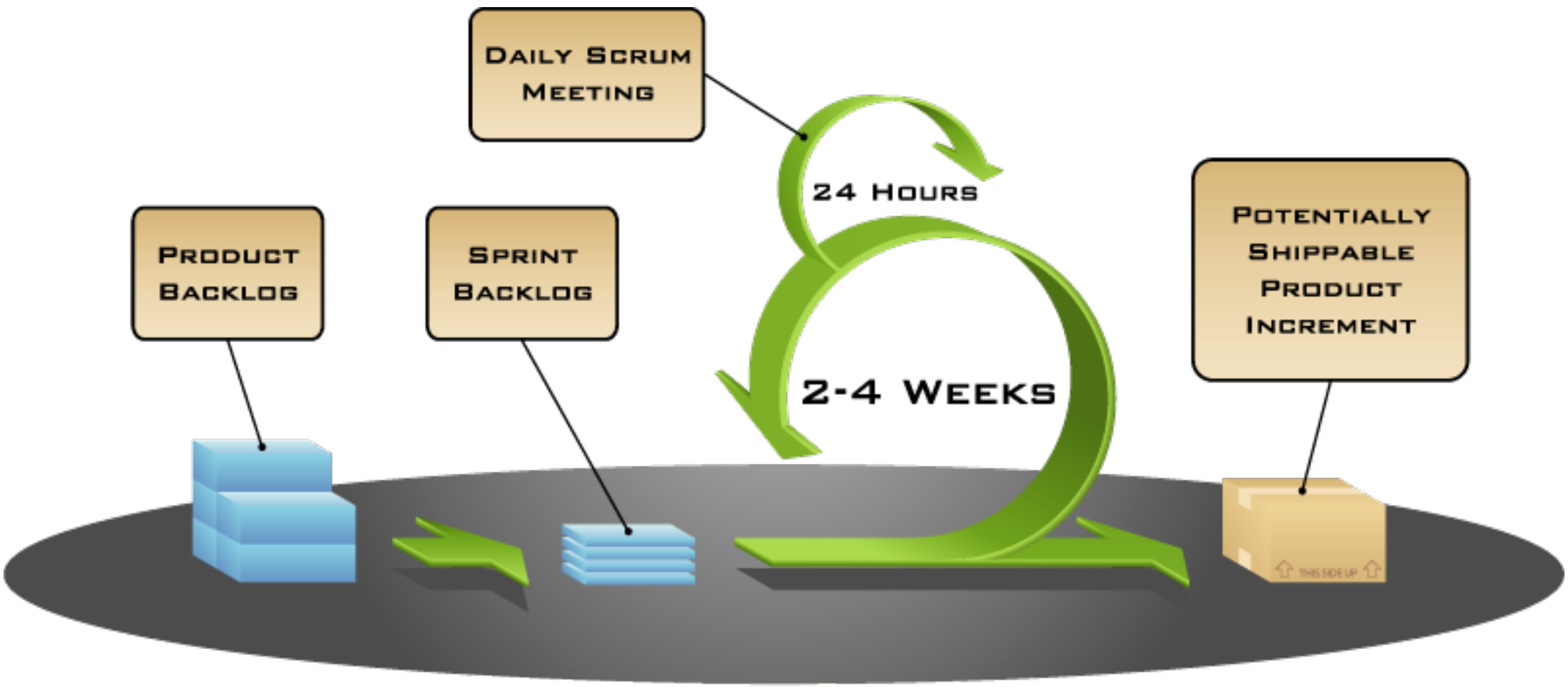
Logistics

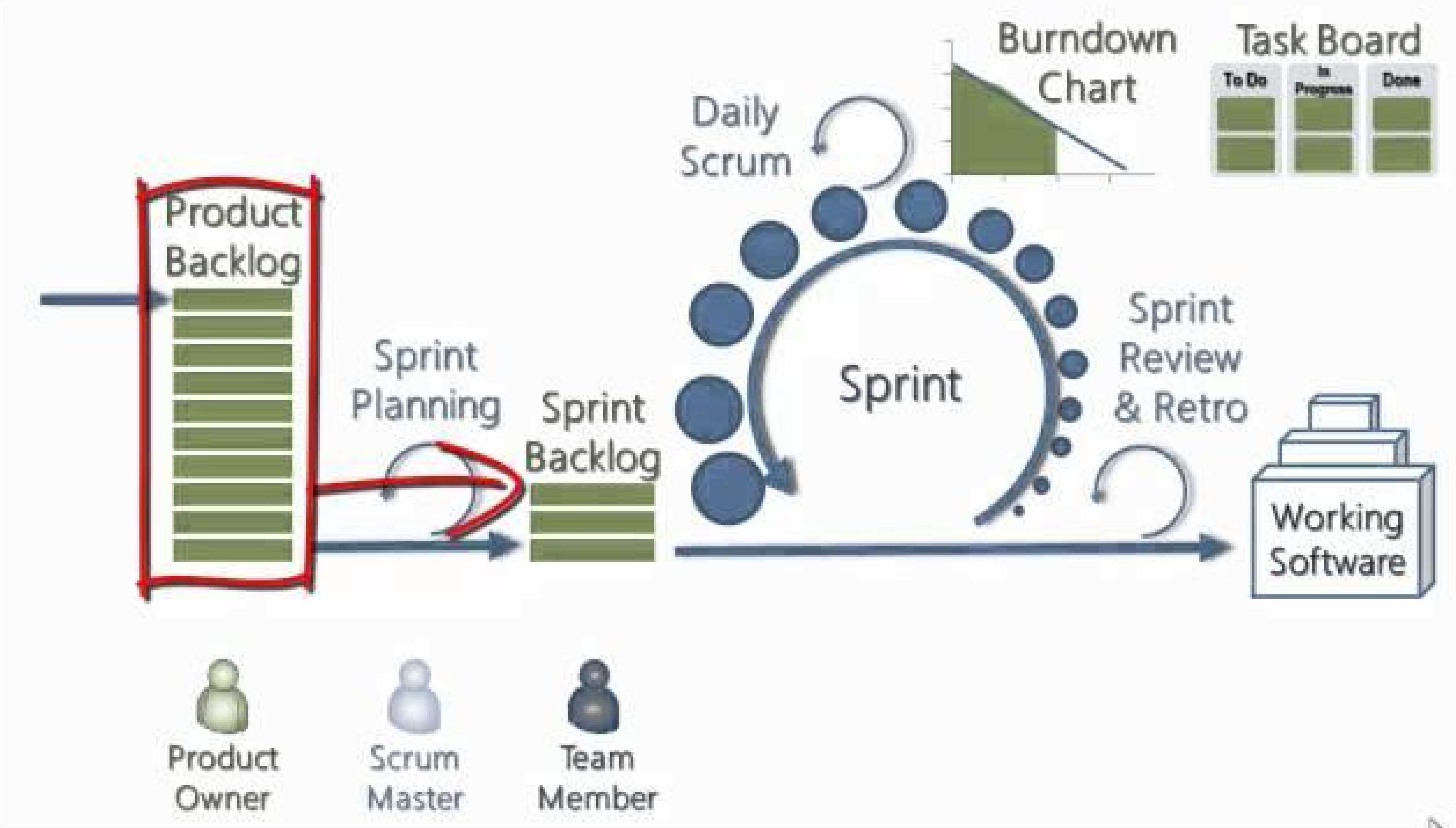
- Access to mentors

Management Plan - Scrum

We will follow a modified “scrum” development process.

The video on the next slide will explain
the basics in under 2 minutes.

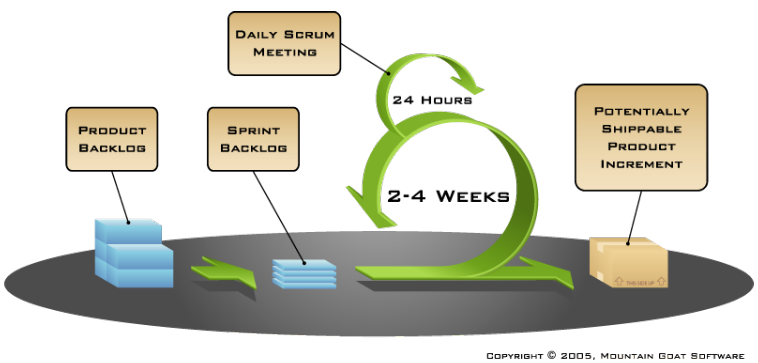



Burndown Chart
Task Board
To Do
In Progress
Done
Daily Scrum
Product Backlog
Sprint Planning
Sprint Backlog
Sprint
Sprint Review & Retro
Working Software
Product Owner
Scrum Master
Team Member

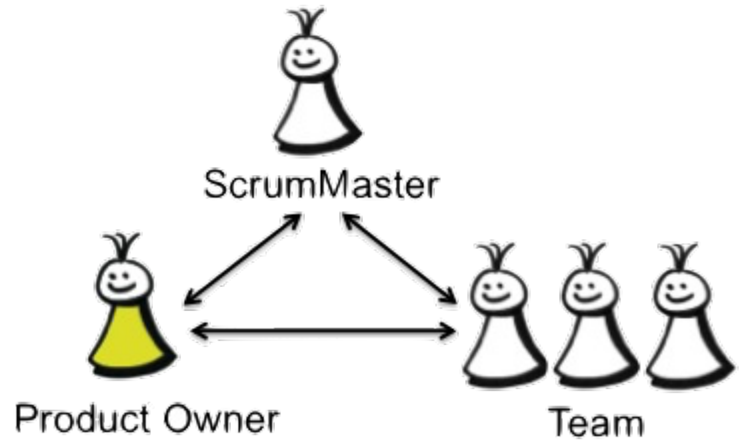
Management Plan

Scrum style project management

- 7 sprints
- 2 weeks each sprint
- 3 scrum meetings per week



Andrew Hundt



Prof. Kazanzides
Prof. Taylor

Andrew Hundt
Alex Strickland
Shahriar Sefati

Key Dates

Sprint	**Date**	**Task**	**Goal Level**
1	**Feb 19**	Initial Simulation	min
2	**Mar 5**	Initial Arm Integration	min
3	**Mar 19**	Cut file integration Optical tracker integration	min expected
4	**Apr 2**	Milling Physical Simulation	max
5	**Apr 16**	Investigate arm motion planning	max
6	**Apr 30**	Milling integration - *max goal*	max
7	**May 7**	System testing and iteration, Poster Session	expected

Reading List

- CONTROLLED TRUST FORCE INFLUENCE ON AUTOMATIC BONE DRILLING PARAMETERS IN THE ORTHOPEDIC SURGERY
- ROBODOC - surgical robot success story
- Computer-integrated revision total hip replacement surgery: concept and preliminary results
- Force sensing and control for a surgical robot
- An integrated system for cementless hip replacement
- Surgical and Interventional Robotics - Core Concepts, Technology, and Design [Tutorial]
- The DLR Lightweight Robot – Design and Control Concepts for Robots in Human Environments
- Opening the Door to New Sensor-Based Robot Applications — The Reflexxes Motion Libraries
- Online Trajectory Generation Algorithms as an Intermediate Layer between Robot Motion Planning and Control

Reading List (cont.)

- Taylor RH, Mittelstadt BD, Paul HA, Hanson W, Kazanzides P, Zuhars JF, et al. An Image-Directed Robotic System for Precise Orthopaedic Surgery. IEEE Trans on Robotics and Automation. 1994 Jun;10(3):261-275
- Kazanzides P, Zuhars J, Mittelstadt B, Taylor RH. Force Sensing and Control for a Surgical Robot. In: IEEE Intl. Conf. on Robotics and Automation. Nice, France; 1992. p. 612-617
- Zuhars J, Hsia TC. Nonhomogeneous material milling using a robot manipulator with force controlled velocity. In: IEEE Intl. Conf. on Robotics and Automation. Nagoya, Japan; 1995. p. 1461-1467
- Stocco L. Path Verification for Unstructured Environments and Medical Applications. In: ASME Design Automation Conf., Symp. on Mechanisms and Devices for Medical Applications. Pittsburgh, PA; 2001. p. 1103-1108

Questions?