

Progress Update: Detection and Guidance of K-Wire Placement in Pelvic Trauma Surgery

Team: Kinjal Shah and Irina Bataeva

Mentor: Dr. Ali Uneri

CIS2 Project

March 26, 2020

Project Motivation and Goals

Motivation: Improve accuracy to reduce injury while limiting radiation exposure

Objective: Use emerging deep learning methods to:

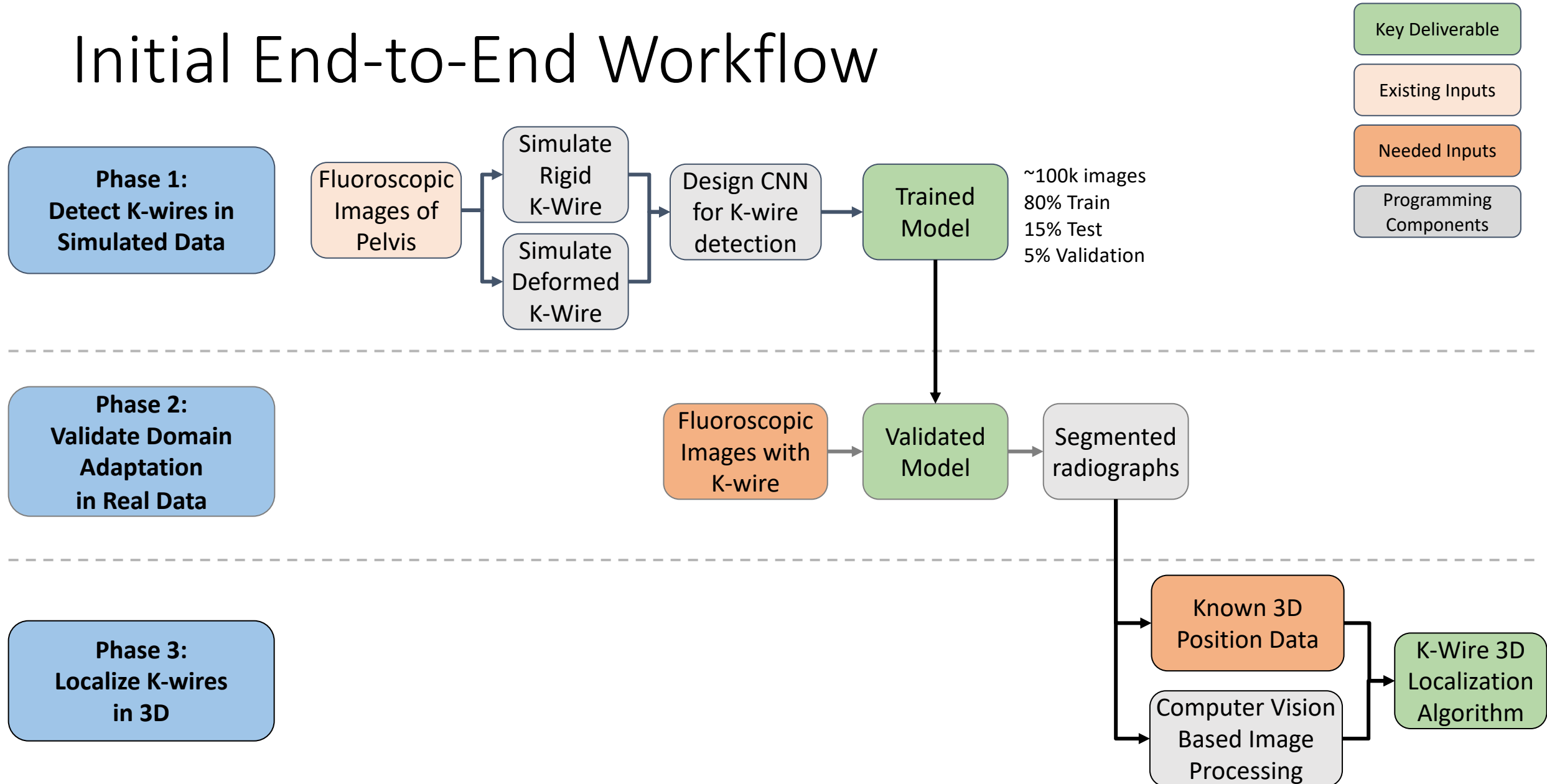
(1) Detect K-wires in 2D radiographs of the pelvis

(2) Localize their 3D pose to provide surgical navigation during fracture fixation – *re-evaluated plan*

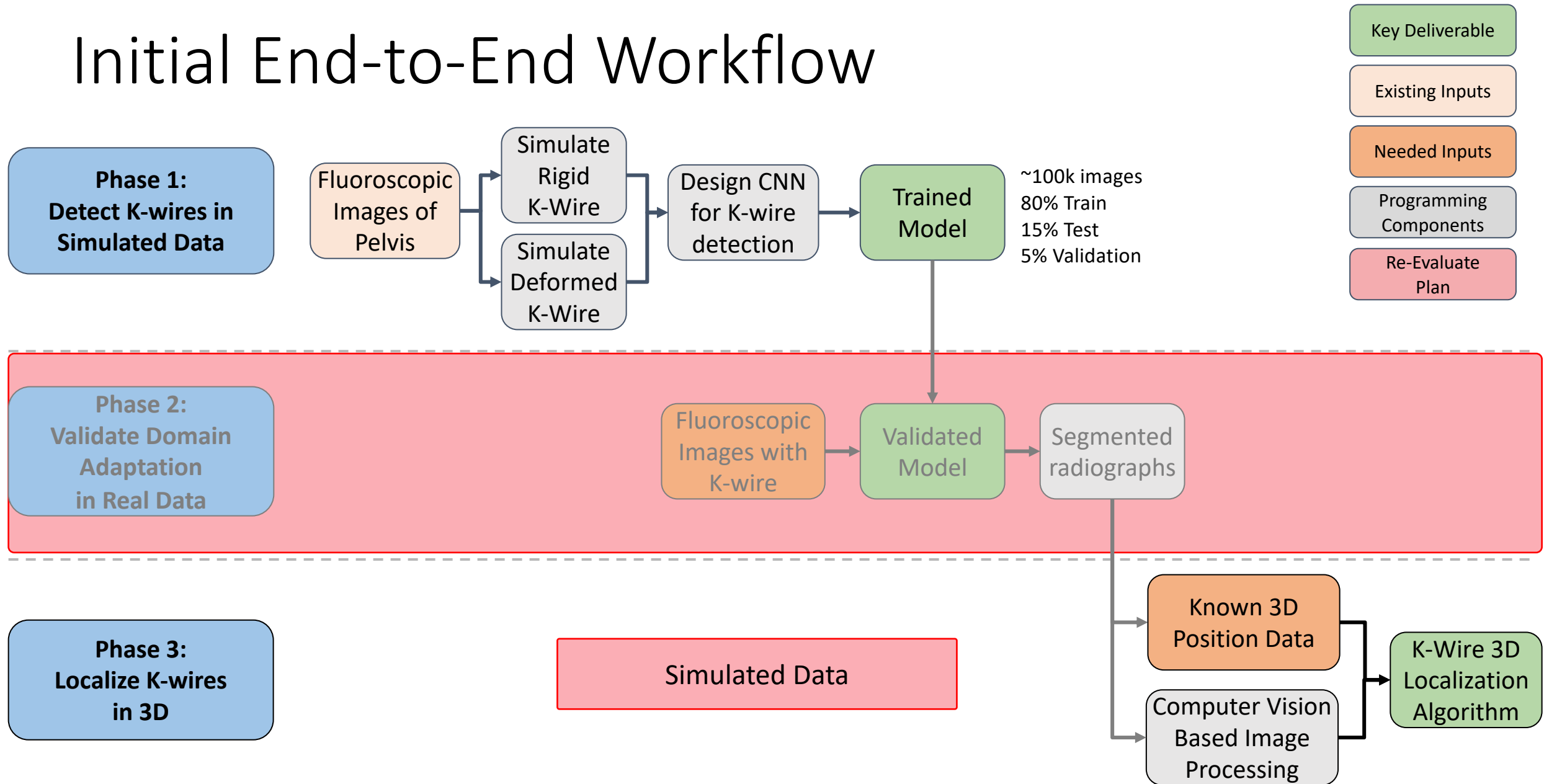
Figures of Merit

- Improved robustness resulting in fewer outliers
- Faster localization through better initialization: **Target < 2 min**
- Improved accuracy of K-Wire Detection: **Target < 1.1±1.6 mm**
- Fewer fluoroscopic images necessary for detection and guidance

Initial End-to-End Workflow

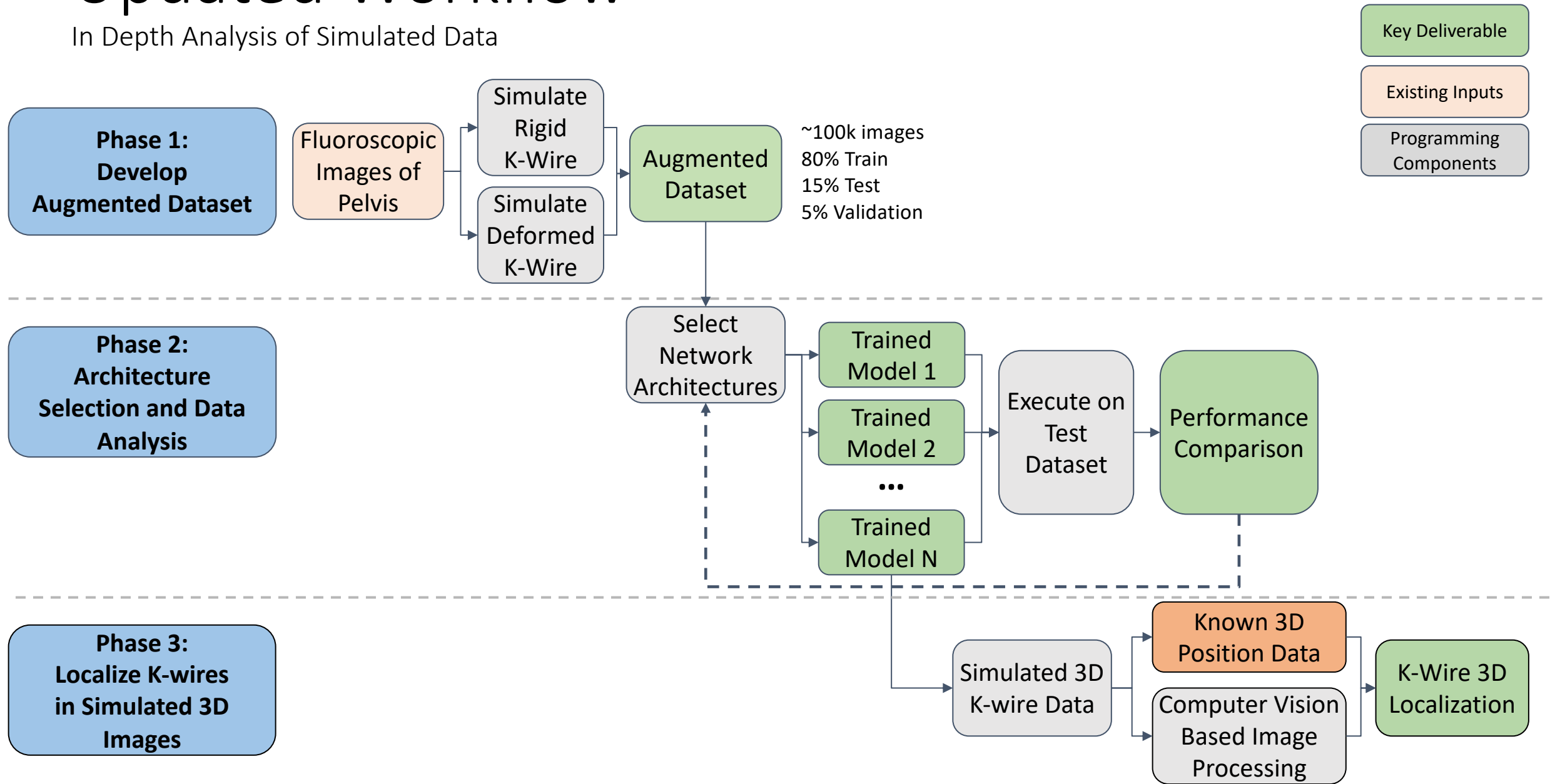


Initial End-to-End Workflow



Updated Workflow

In Depth Analysis of Simulated Data



Deliverables

Minimum (Phase 1): Dataset Generation

- Simulated K-wire dataset with augmented pelvic radiographs
 - Deformed K-wires
 - Rigid K-wires

Expected (Phase 2): Selection of CNN Architecture, Data Analysis

- Report comparing network architectures
- Documentation for trained and validated model to detect K-wire in 2D radiographs
- Figures of merit for simulated data results

Maximum (Phase 3): Simulated 3D Localization and Paper

- 3D Localization
- Conference submission

Dataset Generation

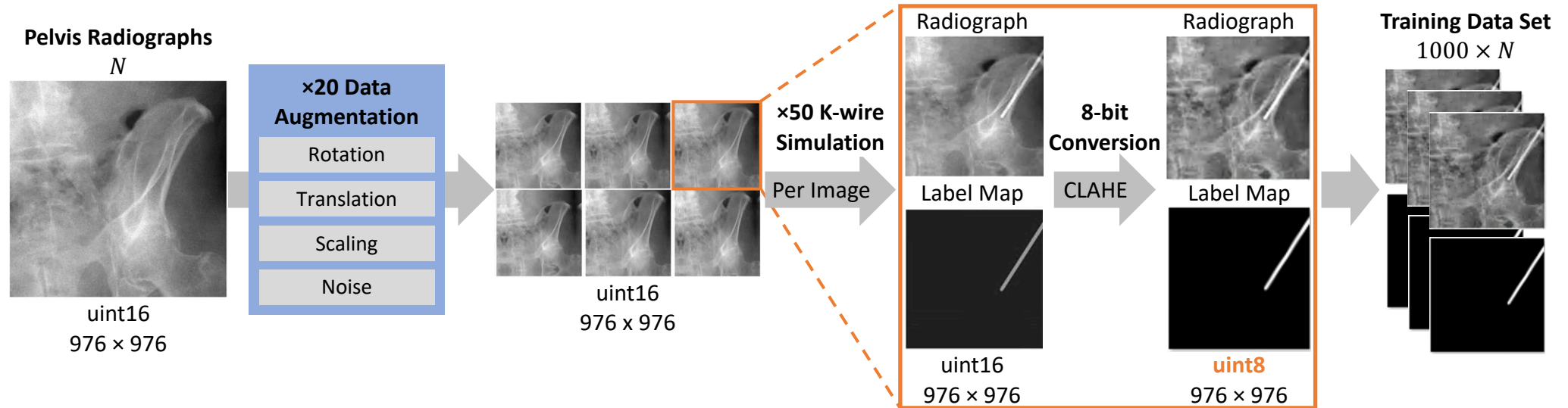


Figure 1. Flowchart for training data set generation. Multiple (N) fluoroscopic images extracted from 3D scans of a cadaveric pelvis specimen undergo data augmentation ($\times 20$), followed by simulated K-wire projections ($\times 50$) to produce $1000 \times N$ images and K-wire label maps for use in training an artificial neural network for K-wire detection.

Data Augmentation Parameters

Imgaug Library

- Scaling $\pm 20\%$
- Translation $\pm 1\%$
- Rotation $\pm 2.5^\circ$
- Random order of operations
- Gaussian Noise (50% of the images)

Based on Wagner, Martin G., et al. "Deep Learning Based Guidewire Segmentation in x-Ray Images." Medical Imaging 2019: Physics of Medical Imaging, 2019, doi:10.1117/12.2512820

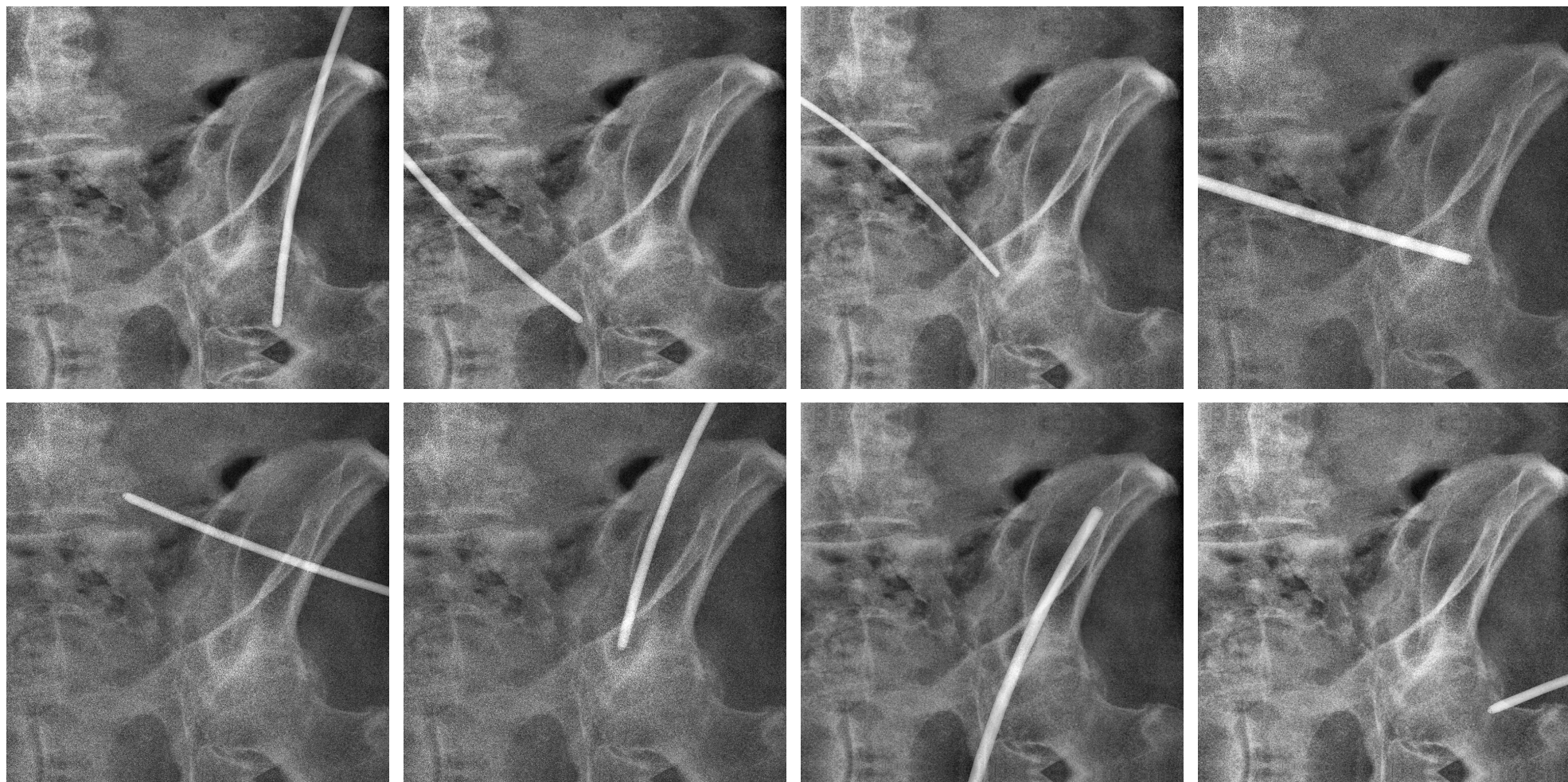
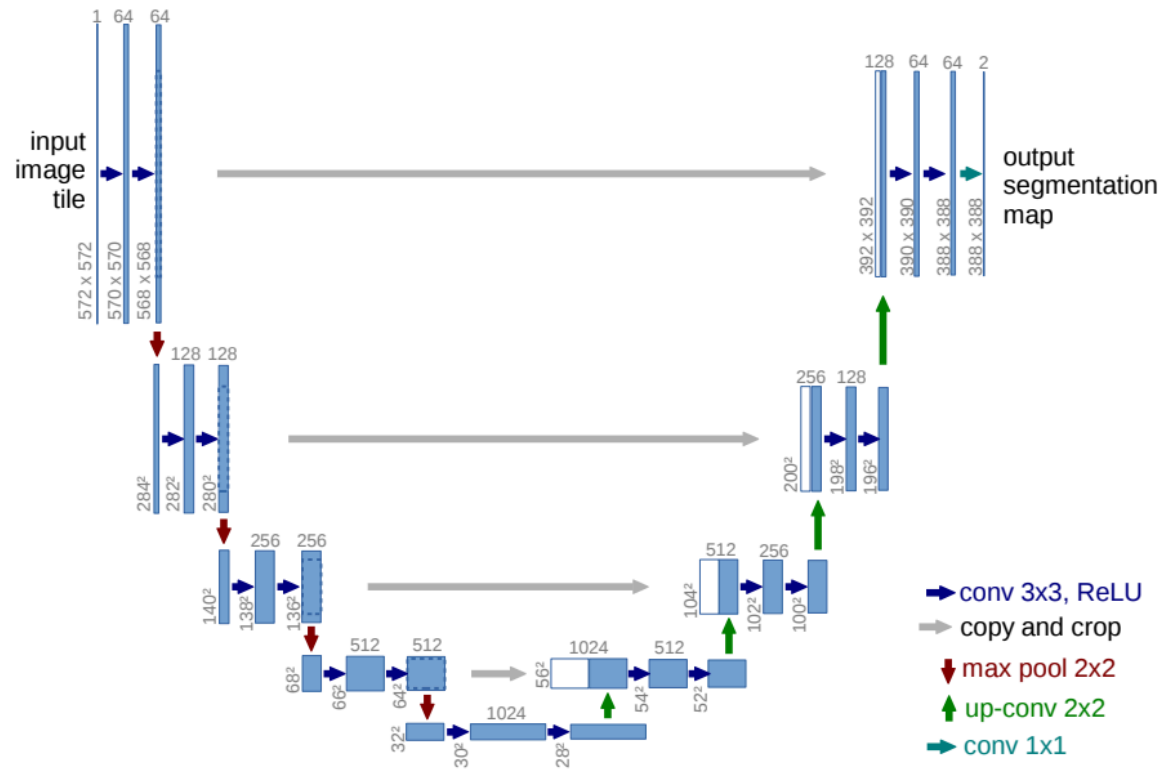


Figure 2. Example images from the generated training data set. Data augmentation is demonstrated as subtle rotations, translations, scaling, and noise applied on a single image from a cadaveric pelvis specimen. Simulated B-spline based K-wire models are projected on the augmented images at varying pose and deformations.

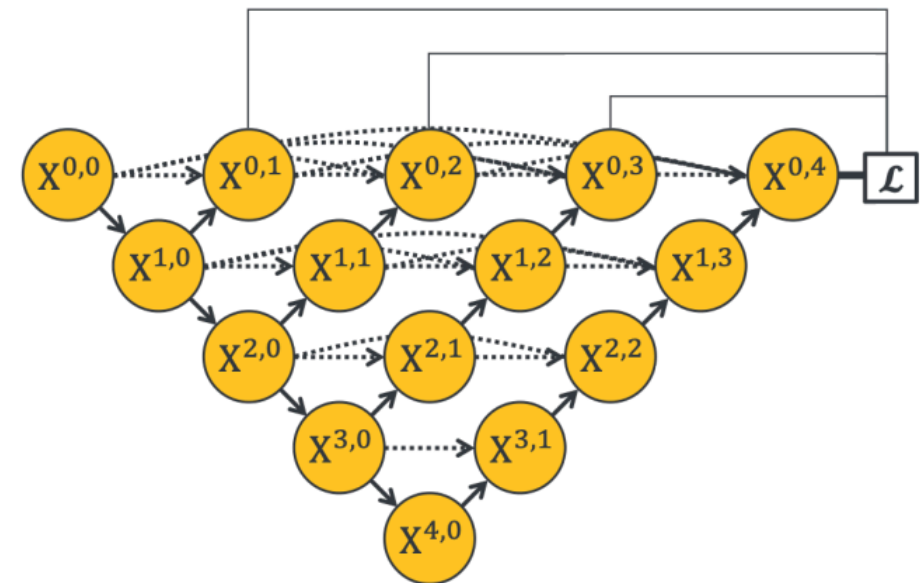
Candidate Architectures

UNet (2015)¹



VS

UNet++ (2019)²



(g) UNet++

[1] Ronneberger, Olaf, et al. "U-Net: Convolutional Networks for Biomedical Image Segmentation." *Lecture Notes in Computer Science Medical Image Computing and Computer-Assisted Intervention – MICCAI 2015*, 2015, pp. 234–241., doi:10.1007/978-3-319-24574-4_28.

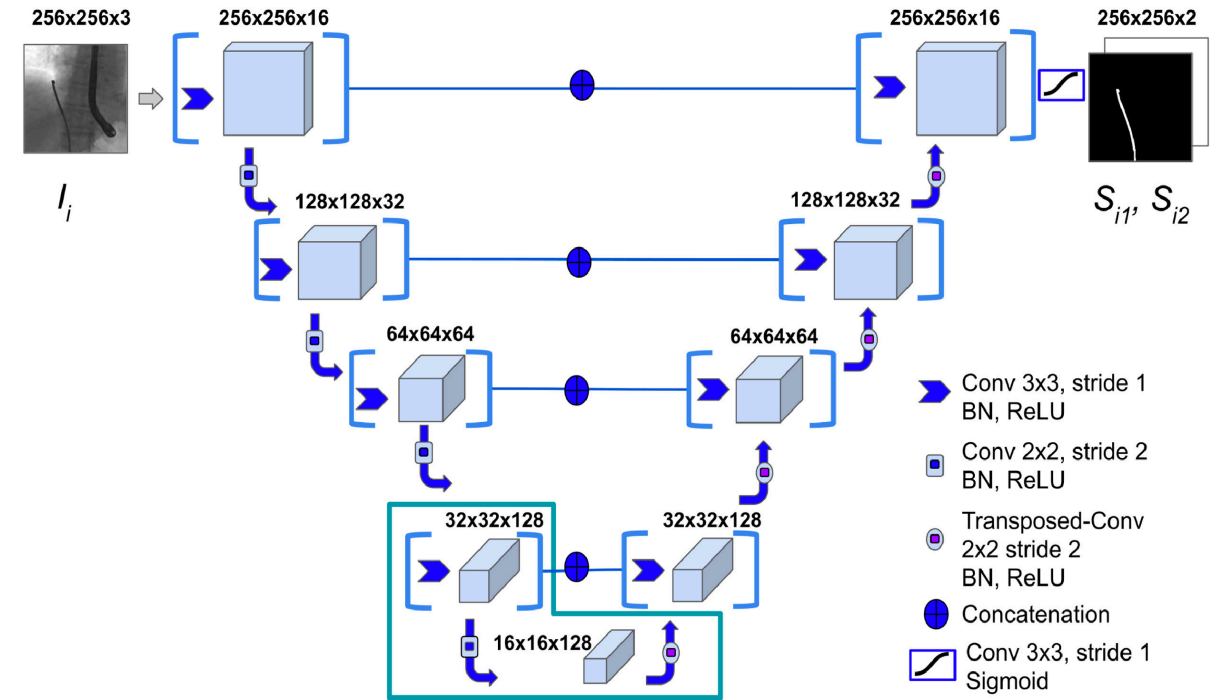
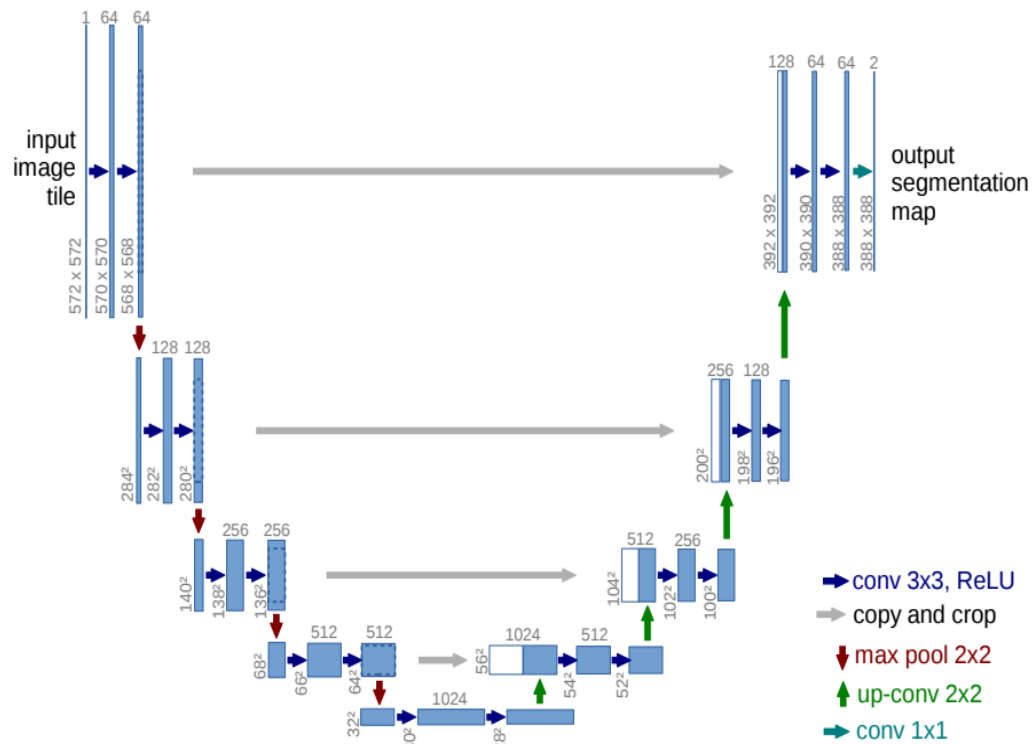
[2] Zhou, Zongwei, et al. "UNet : Redesigning Skip Connections to Exploit Multiscale Features in Image Segmentation." *IEEE Transactions on Medical Imaging*, 2019, pp. 1–1., doi:10.1109/tmi.2019.2959609.

Candidate Architectures

UNet (2015)¹

VS

UNet Light (2020)²



[1] Ronneberger, Olaf, et al. "U-Net: Convolutional Networks for Biomedical Image Segmentation." *Lecture Notes in Computer Science Medical Image Computing and Computer-Assisted Intervention – MICCAI 2015*, 2015, pp. 234–241., doi:10.1007/978-3-319-24574-4_28.

[2] Gherardini, Marta, et al. "Catheter Segmentation in X-Ray Fluoroscopy Using Synthetic Data and Transfer Learning with Light U-Nets." *Computer Methods and Programs in Biomedicine*, vol. 192, 2020, p. 105420., doi:10.1016/j.cmpb.2020.105420.

Candidate Architectures

If UNet Unsuccessful:

- Mask R-CNN (2018)¹
- Mask RCNN++ (UNet++ with Mask R-CNN) (2019)²

[1] He, Kaiming, et al. "Mask R-CNN." *2017 IEEE International Conference on Computer Vision (ICCV)*, 2017, doi:10.1109/iccv.2017.322.

[2] Zhou, Zongwei, et al. "UNet : Redesigning Skip Connections to Exploit Multiscale Features in Image Segmentation." *IEEE Transactions on Medical Imaging*, 2019, pp. 1–1., doi:10.1109/tmi.2019.2959609.

Initial Milestones

Milestone	Planned Date	Expected Date	Status
Complete Development of Training Set	Monday, March 16	Monday, March 16	On Track
Collation of existing data	Monday, March 2	Monday, March 2	On Track
Collation of publicly available medical images	Monday, March 2	Monday, March 2	On Track
Data augmentation of pelvic images with simulated K-wires	Monday, March 16	Monday, March 16	On Track
Obtain Trained Model	Friday, March 20	Friday, March 20	On Track
Identify candidate CNN architectures based on literature review	Friday, February 28	Friday, February 28	On Track
Establish necessary architecture for chosen solution	Wednesday, March 4	Wednesday, March 4	On Track
Train CNN	Monday, March 16	Monday, March 16	On Track
Code Documentation	Friday, March 27	Friday, March 27	On Track
Obtain Figures of Merit - Simulated Data	Monday, April 6	Monday, April 6	On Track
Define Validation Process	Tuesday, March 10	Tuesday, March 10	On Track
Conduct robust testing on Training dataset	Friday, March 20	Friday, March 20	On Track
Obtain Figures of Merit - Real Data	Monday, April 20	Monday, April 20	On Track
Definition of experimental plan and validation process	Tuesday, March 20	Tuesday, March 20	On Track
Data acquisition	Friday, April 10	Friday, April 10	On Track
Code Documentation	Monday, April 27	Monday, April 27	On Track
3D Localization Algorithm Developed	Friday, May 1	Friday, May 1	Under Re-evaluation
Literature Review Report	Monday, April 20	Monday, April 20	Under Re-evaluation
Initial program draft complete, validation initiated	Friday, May 1	Friday, May 1	Under Re-evaluation
Final Poster Presentation/Report	Tuesday, May 5	Tuesday, May 5	On Track
Conference Submission	Summer 2020	Summer 2020	On Track

Updated Milestones

Milestone	Planned Date	Expected Date	Status
Complete Development of Training Set	Monday, March 16	Monday, March 16	On Track
Collation of existing data	Monday, March 2	Monday, March 2	Complete
Data augmentation of pelvic images with simulated K-wires	Monday, March 16	Monday, March 16	Complete
Experiment with augmentation strategies	Monday, March 23	Monday, March 23	Complete
Code documentation	Friday, March 27	Friday, March 27	On Track
Obtain Trained Model	Friday, March 20	Monday, April 13	Delayed
Identify CNN architectures based on literature review	Friday, February 28	Friday, February 28	Complete
Establish necessary architecture for chosen solutions	Wednesday, March 4	Wednesday, March 4	Delayed*
Overfitting Test	Monday, March 30	Monday, March 30	On Track
Train CNN on a complete dataset	Monday, March 16	Monday, April 6	Delayed
Code documentation	Monday, April 13	Monday, April 13	On Track
Obtain Figures of Merit - Simulated Data	Monday, April 24	Monday, April 24	On Track
Define Validation Process	Tuesday, March 10	Tuesday, March 10	Delayed – In Progress*
Conduct robust testing on dataset	Friday, March 20	Monday, April 10	Delayed
Comparison of network architectures and evaluation of model selection	Friday, April 17	Friday, April 17	On Track
Code documentation	Monday, April 24	Monday, April 24	On Track
3D Localization Algorithm Developed	Friday, May 1	Friday, May 1	Under Re-evaluation
Literature Review Report	Monday, April 20	Monday, April 20	Under Re-evaluation
Initial program draft complete, validation initiated	Friday, May 1	Friday, May 1	Under Re-evaluation
Code Documentation	Monday, April 27	Monday, April 27	On Track
Final Poster Presentation/Report	Tuesday, May 5	Tuesday, May 5	On Track
Conference Submission	Summer 2020	Summer 2020	On Track

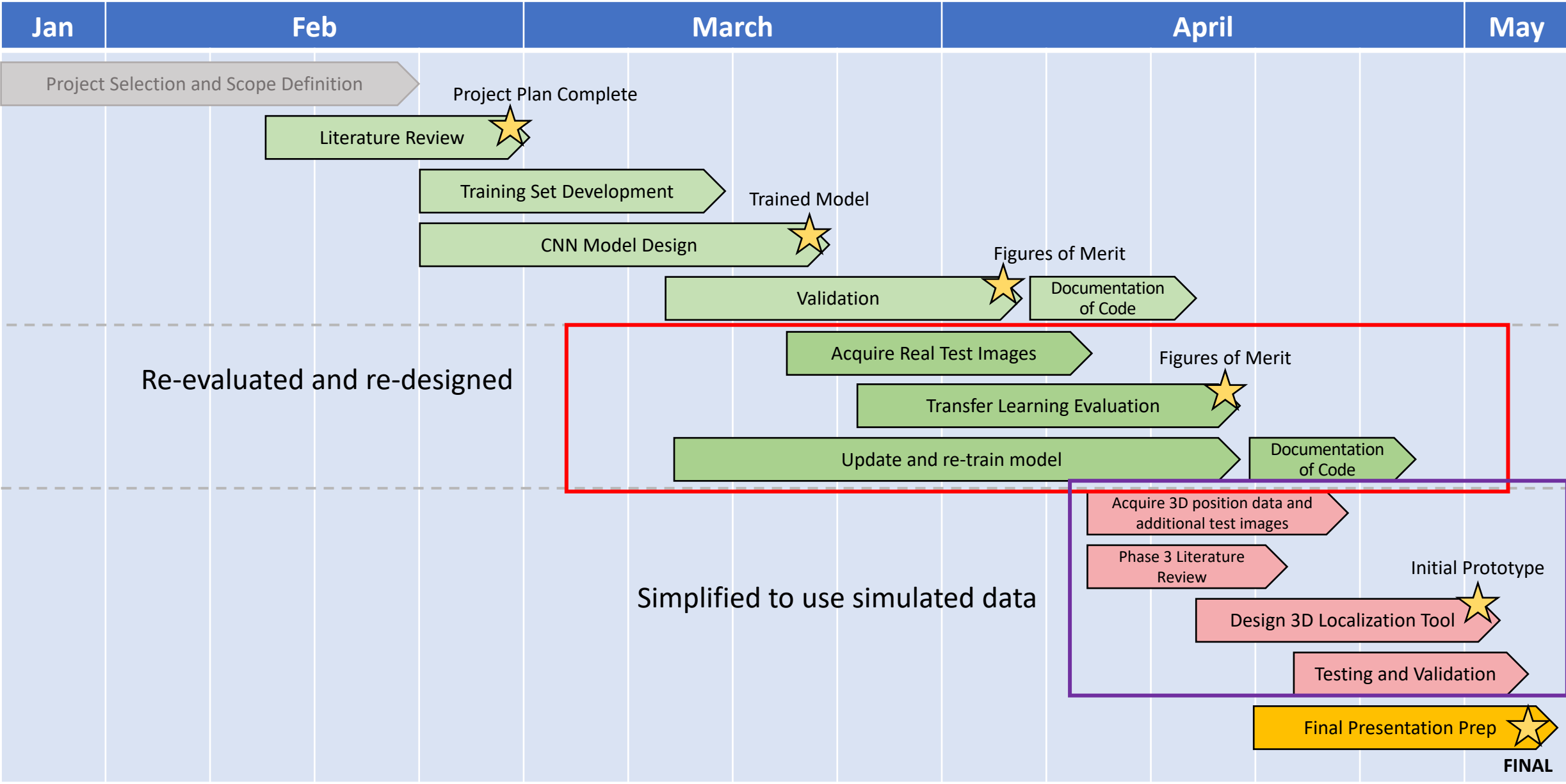
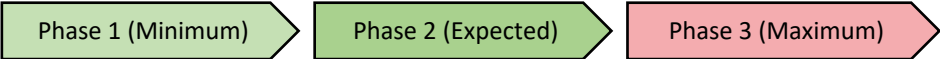
* Expanded Scope

Dependencies

Dependency	Contact	Date Required	Status	Solution	Contingency
Availability of real radiographs of the pelvis	Dr. Ali Uneri	2/28	Resolved	Leverage software tools and radiographs provided by the I-STAR lab	Generate image set using radiographs simulated from CT
Access to C-arm, phantoms, and surgical instruments	Dr. Jeffrey Siewerdsen, Dr. Ali Uneri	2/26	Resolved	Access to all equipment to be provided by I-STAR, Rohan Vijayan will assist with C-arm operation	Undergo training if significant amount of data needs to be collected
Computational Resources	Dr. Ali Uneri	2/27	Resolved	Access to a shared GPU cluster at I-STAR, dedicated lab workstation, and personal laptops	Request access to resources at LCSR
I-STAR lab Git repository access	Dr. Ali Uneri	2/21	Resolved	Dr. Uneri will initiate and share a dedicated repository at https://git.lcsr.jhu.edu/	
Cadaver Access	Dr. Jeffrey Siewerdsen	3/15	Available if needed	Cadaver studies (for related projects) are planned for upcoming weeks.	Phantoms
Access to real images with K-wires	Dr. Ali Uneri	3/20	Under Evaluation	If images not are available, we will be able to obtain additional images with phantoms	
Access to scripts / solutions for data generation and training	Dr. Ali Uneri	NA	Resolved	Jupyter notebooks, TensorFlow, PyTorch, OpenCV	

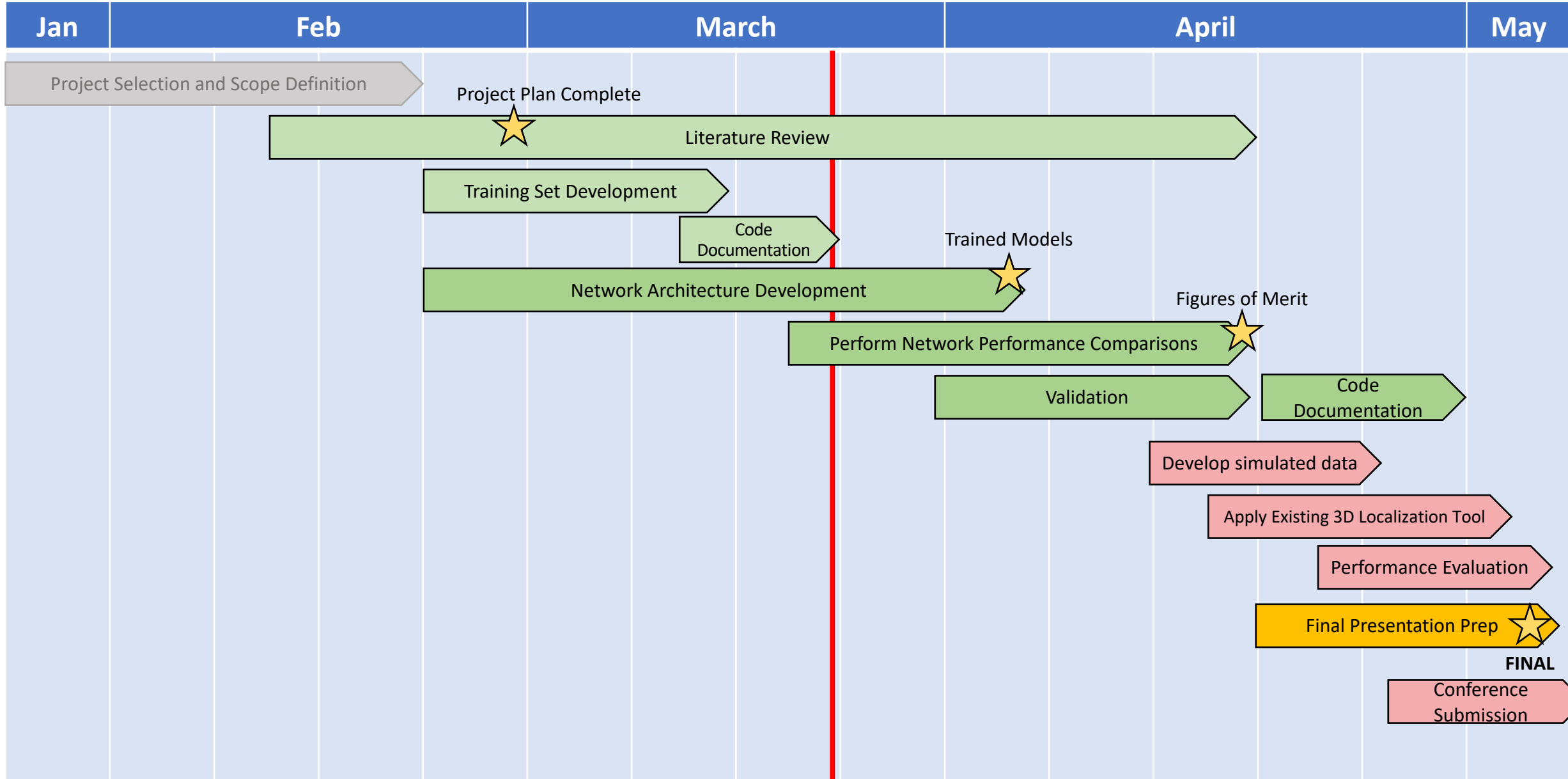
Original Schedule

Key



Updated Schedule

Key



Team Management

Responsibility Ownership

Irina Bataeva	Kinjal Shah
<ul style="list-style-type: none">• K-wire images dataset generation	<ul style="list-style-type: none">• Training model design and development• Model evaluation

Meeting Cadence

- Weekly meetings as a group every Sunday, Wednesday
- Weekly meetings with Dr. Ali Uneri on Fridays *subject to change

Collaboration

- Code storage and version control on GitLab at <https://git.lcsr.jhu.edu/>