CPS: Synergy: Integrated Modeling, Analysis and Synthesis of Miniature Medical Devices

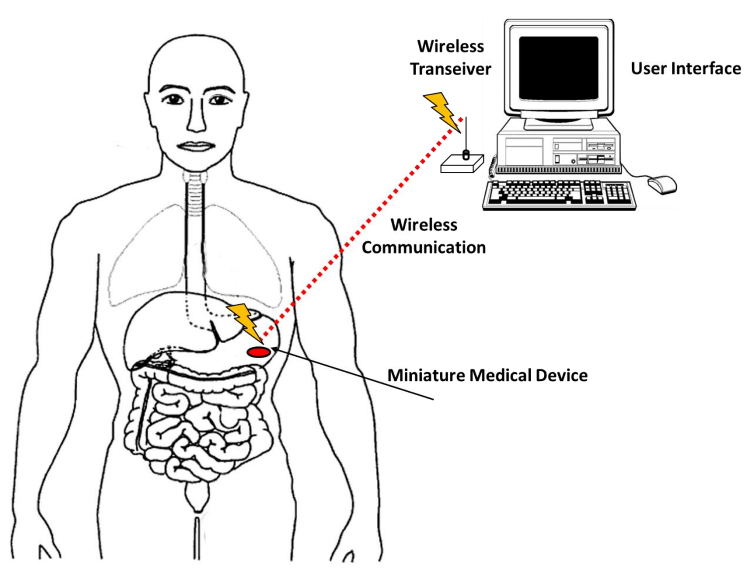
Addisu Taddese[1,2], Marco Beccani[1], Hakan Tunc[2], Ekawahyu Susilo[1], Péter Völgyesi[2], Ákos Lédeczi[2], **Pietro Valdastri**[1]

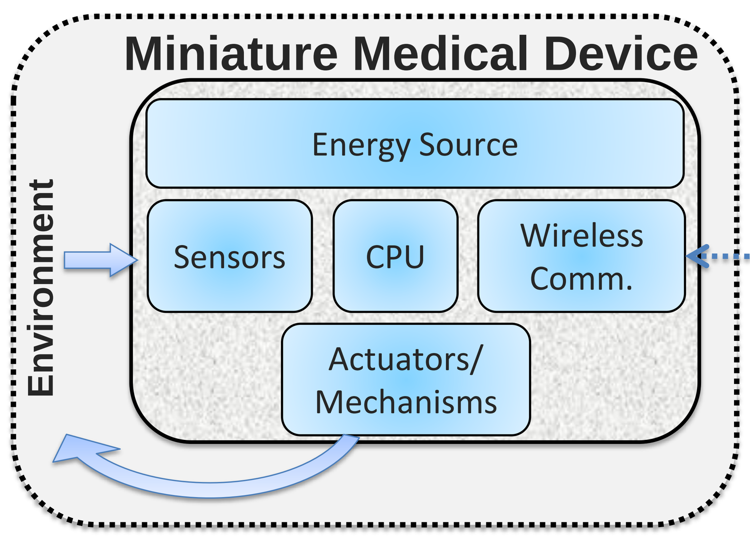
[1]The STORM Lab
Vanderbilt University

[2]INSTITUTE FOR SOFTWARE INTEGRATED SYSTEMS
Vanderbilt University

BACKGROUND

Miniature medical devices are classical CPS that can operate autonomously within the human body to augment surgeons' ability to diagnose, prevent, monitor, and cure diseases



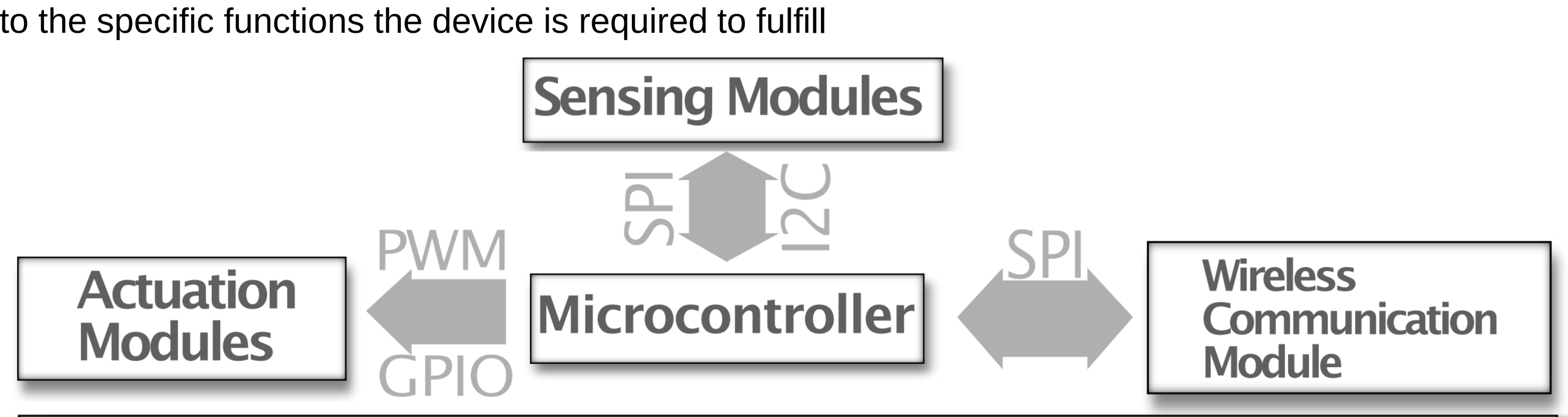


- Human machine interface
- Other miniature devices

Colorectal cancer strikes more than 170,000 in the USA each year and kills approximately 50,000 [1] with a projected 62% increase by 2030 [32]. If we are successful in promoting the implementation of a painless alternative to traditional colonoscopy, this could have a transformative impact on medicine.

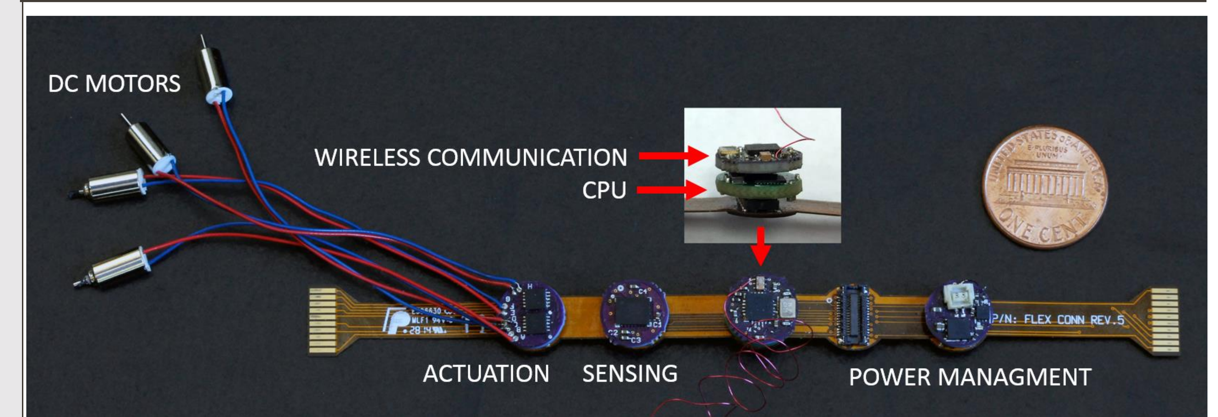
DESIGN CONSIDERATIONS

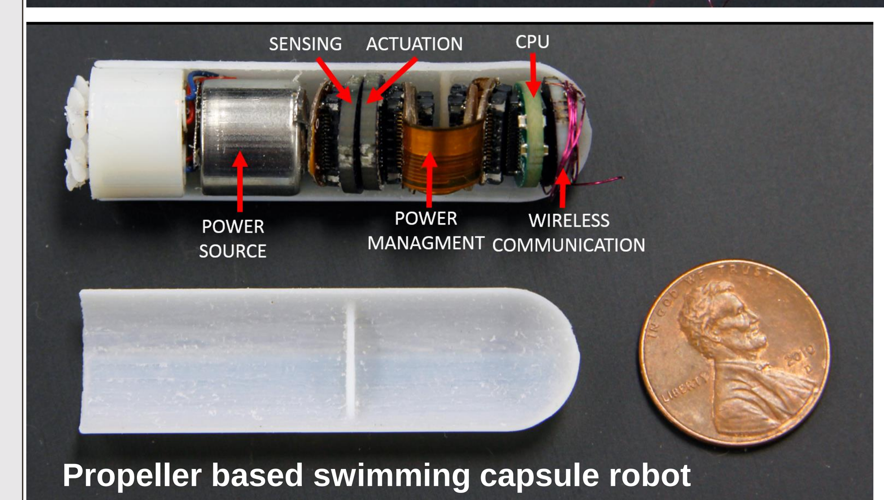
The CPS design framework must address crosscutting constraints such as (1) size – ideally, a capsule device should be small enough to swallow or to enter natural orifices without requiring a dedicated incision; (2) power consumption – given the limited space available onboard, energy is limited; (3) communication bandwidth – wireless signals must be transmitted through the human body with a sufficient data rate; (4) fail safe operation – since the device is deep inside the human body, the user has no access to it; and (5) effective interaction with the target site, according to the specific functions the device is required to fulfill



Common hardware architecture of MCRs that can be exploited to create a generic modular platform

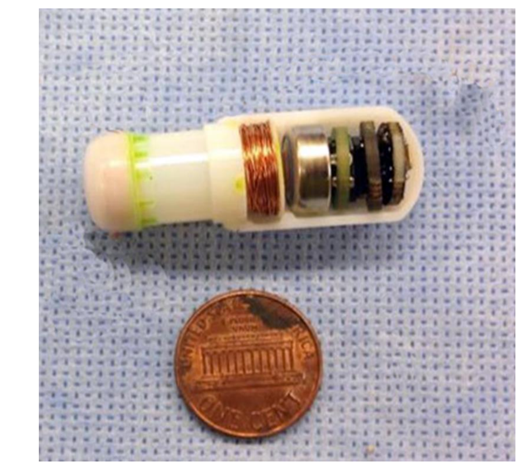
HARDWARE PLATFORM



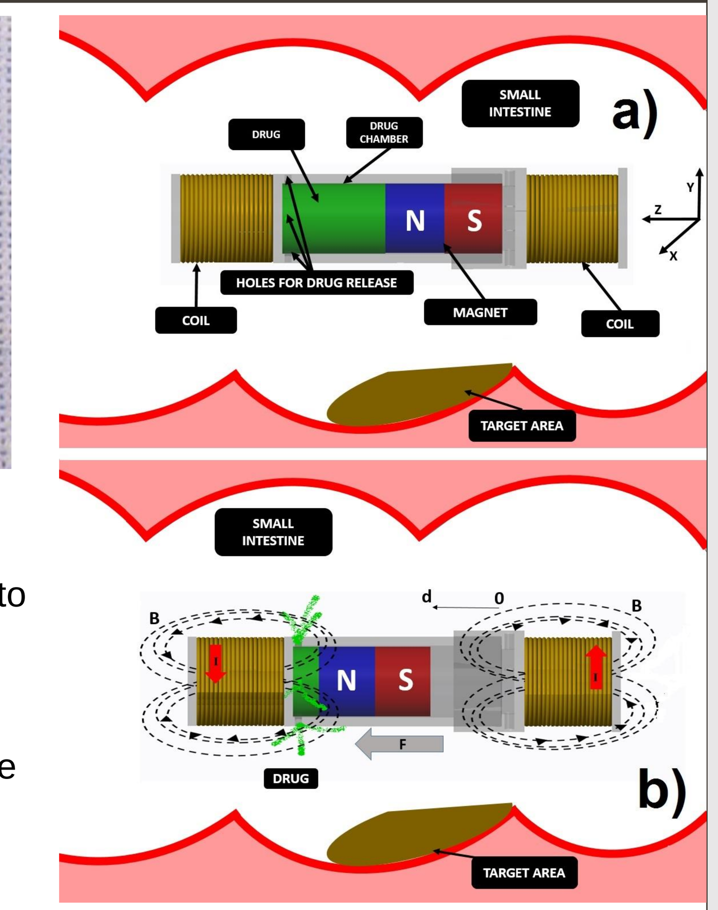


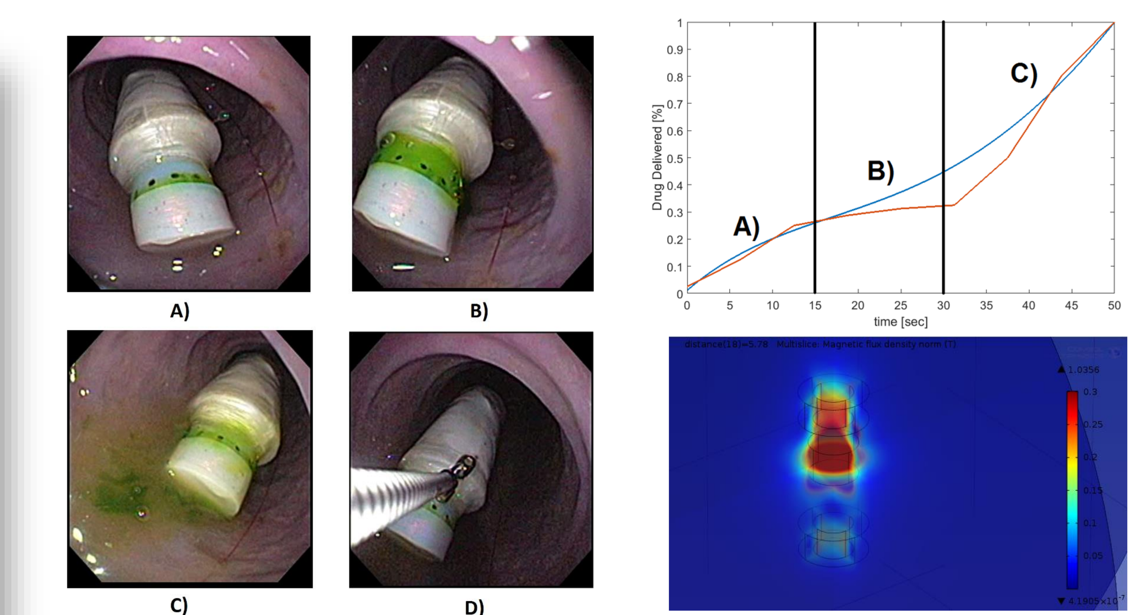
The flexible circuit with hardware modules before folding in a shape that can be integrated inside an MCR. The flexible circuit can host up to five different modules. In this case the wireless communication module is plugged on the CPU module in the central slot. The other slots are respectively hosting an actuation module, a sensing module and the power managing module.

DRUG DELIVERY CAPSULE ROBOT



To seed our collection of design templates, the hardware platform was used to build a drug delivery capsule. The data gathered using this capsule is used to validate a model which is fed back to the design environment



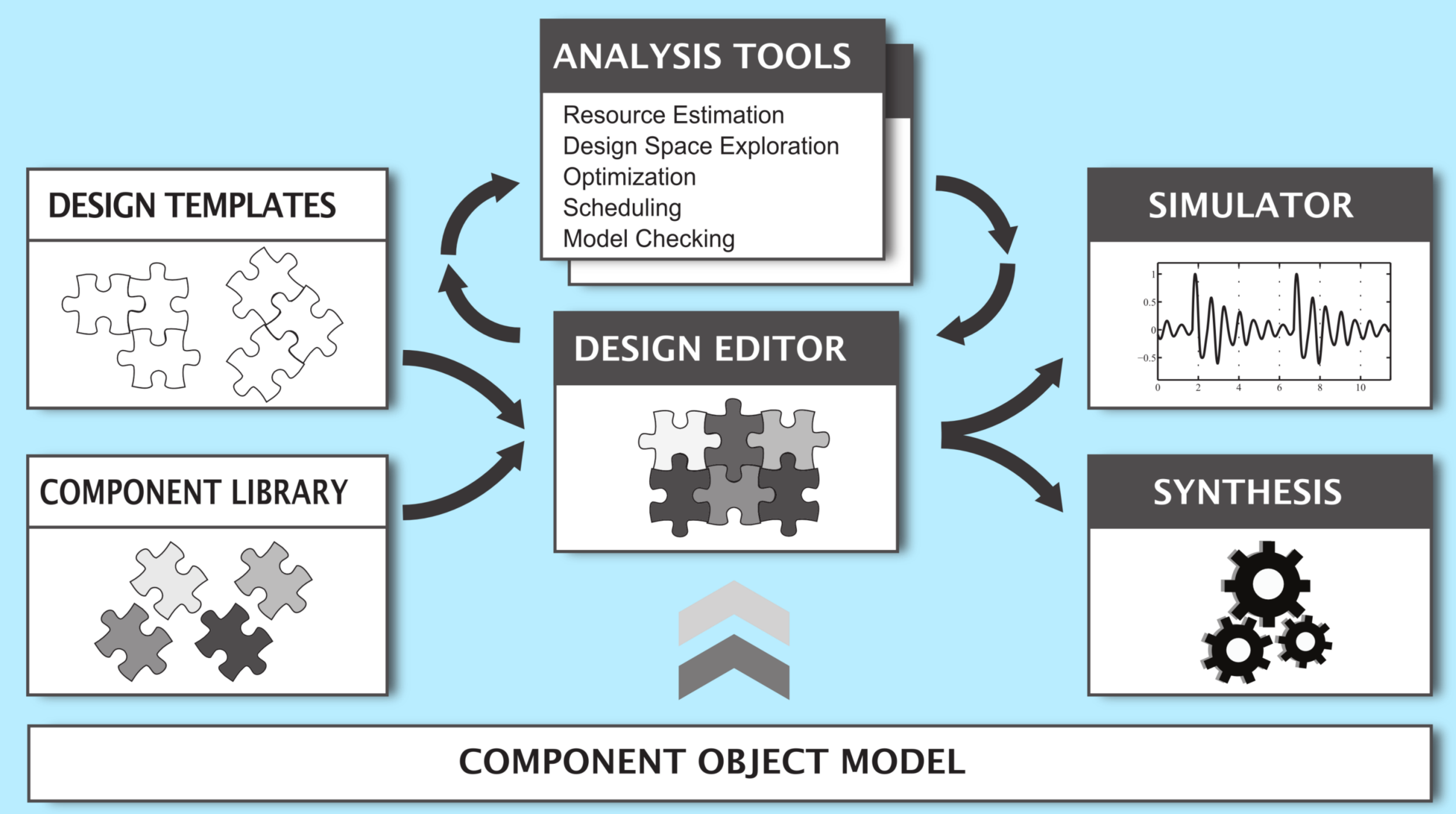


DESIGN ENVIRONMENT

The objective of this project is to create a focused cyber-physical design environment to accelerate the development of miniature medical devices.

A versatile **component model** will provide the structural and semantic foundation for the entire model-based design flow

A pre-built **component library** will provide the building blocks for design construction

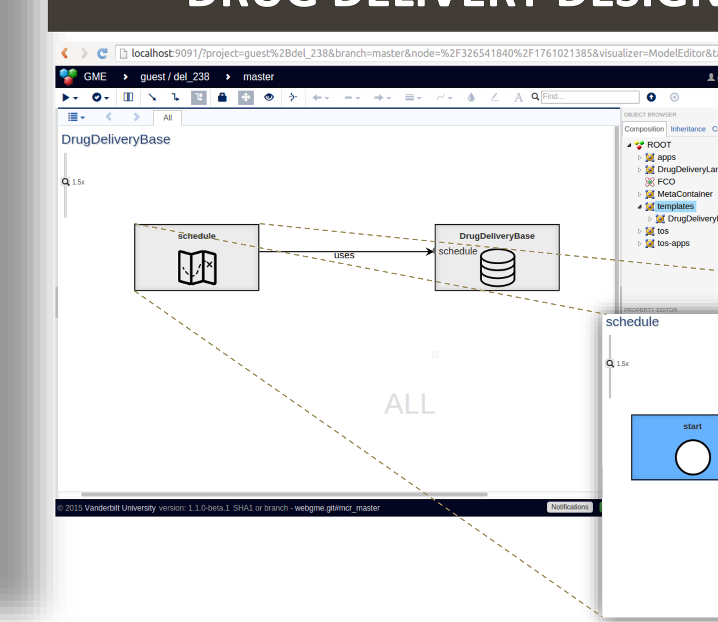


An integrated **simulation framework** will provide insight into the dynamic behavior of the design before manufacturing

Static analysis tools will provide performance and cost estimates before system **synthesis**

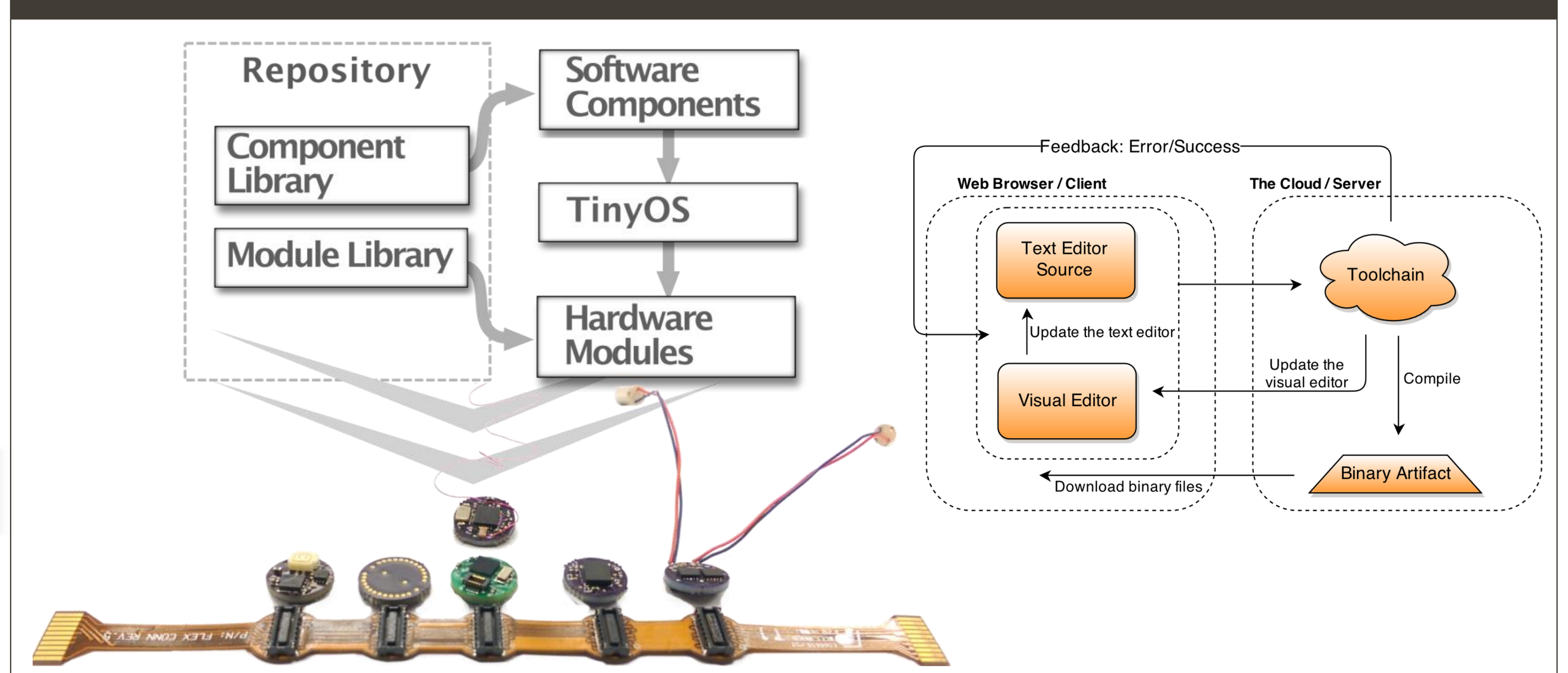
The goal is to **synthesize** application software, printed circuit board (PCB), computer aided design (CAD) models, and bill of materials with cost estimates with minimal manual guidance

DRUG DELIVERY DESIGN ENVIRONMENT



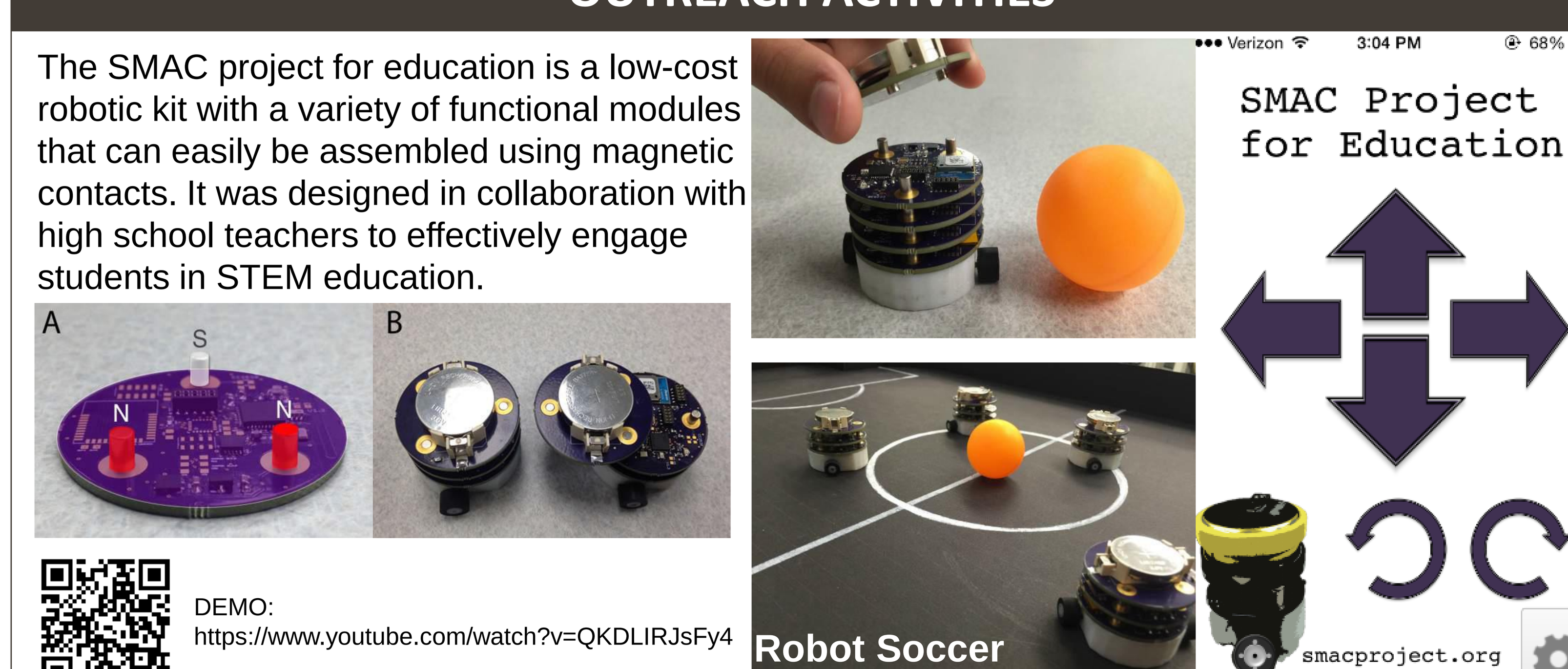
The design environment can be used to create a drug delivery schedule in an intuitive manner based on a drug viscosity model. It is then used to generate the code to implement it in a capsule robot.

SOFTWARE PLATFORM



OUTREACH ACTIVITIES

The SMAC project for education is a low-cost robotic kit with a variety of functional modules that can easily be assembled using magnetic contacts. It was designed in collaboration with high school teachers to effectively engage students in STEM education.



DEMO:
https://www.youtube.com/watch?v=QKDLIRJsFy4

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CONTACT
Pietro Valdastri, PhD – Assistant Professor of Mechanical Engineering
Director of the STORM Lab – WEB: http://my.vanderbilt.edu/stormlab
Email: p.valdastri@vanderbilt.edu
Open source @ http://pillforge.github.io

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