



Memorial Sloan Kettering  
Cancer Center

**DigITs**

DIGITAL, INFORMATICS, TECHNOLOGY

# To infinity... and beyond!

Tech Incubation Internship, Summer 2020

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A close-up, cinematic shot of the character Winston from the game Overwatch. He is a large, blue, gorilla-like creature with a thick, grey beard and a determined, slightly angry expression. His eyes are glowing orange. He is wearing a dark, tactical helmet with orange triangular accents. The background is dark and out of focus, suggesting an industrial or military setting.

**OVERWATCH™**

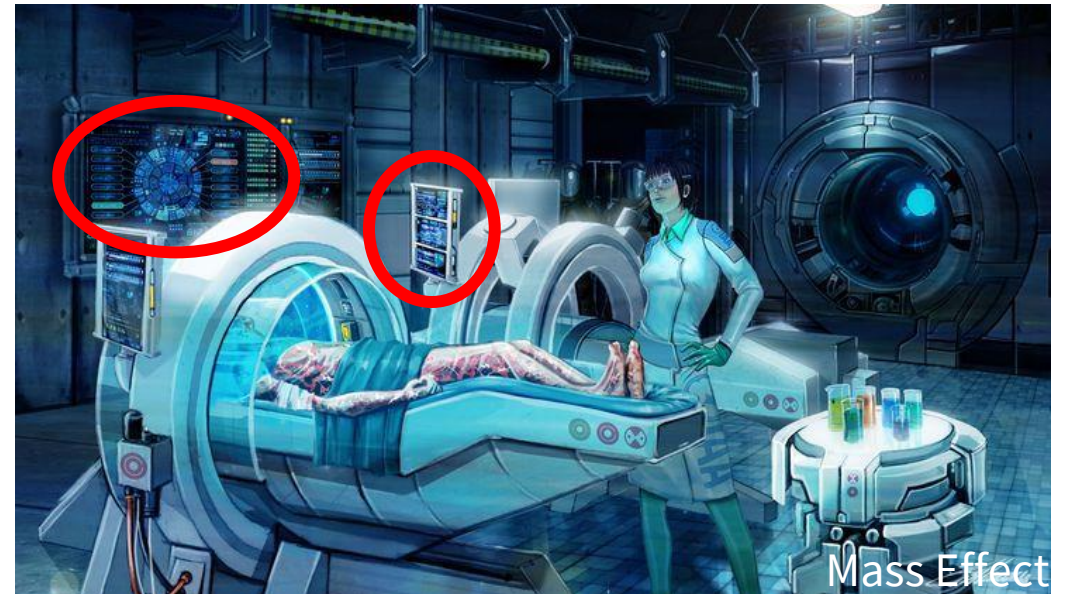
*ANIMATED SHORT*  
**RECALL**

# Better UI is a sci-fi dream

But is it only a sci-fi dream?



Star Wars Combine game



Mass Effect

# An ambient future: Seamless technology integration

Sci-fi "medical bay," in your home

## Why ambience?

Zero-friction, seamless technology

Can't change human behavior

Reduce patient burnout;  
"lower activation energy"

Comfortable, natural  
home atmosphere

Reduced duplicate computation

## MSK START solutions

Integrated systems with integrated UI means **unified user experience** and a cohesive, reliable, multifunctional home system

Let's make **technology that works around the user**, so the user doesn't have to work around the technology

It's hard to motivate patients to self-report, so instead, let's **reduce their workload** by offsetting it to cutting-edge technology

MSK has moved toward outpatient facilities like Josie Robertson, for patient comfort and lower infection risk. Next step? **Keep the patient home.**

**One integrated system** means one user portal, one clinician software app, one databank, one project, one upkeep team, and one marketing campaign.

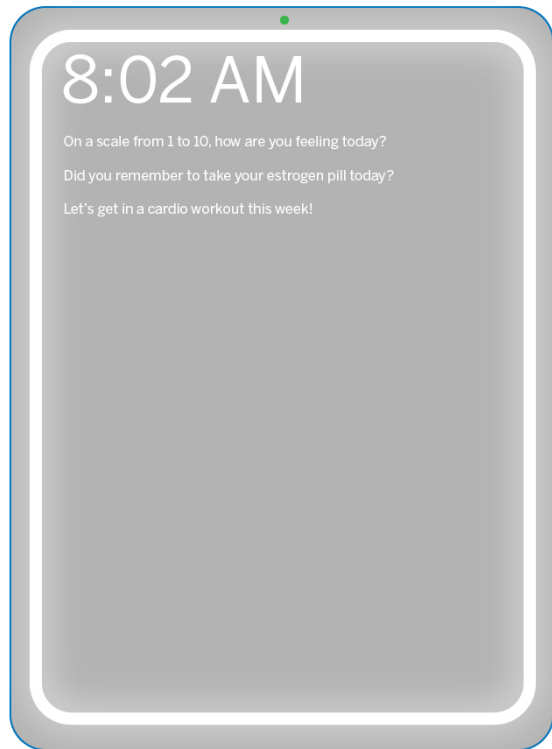
MSK  START

Symptoms Tracking at Real Time

# MSK START: Bringing the clinic to your bathroom

Integrated remote monitoring system for pre-treatment, during treatment, and post-treatment

## "Hub"



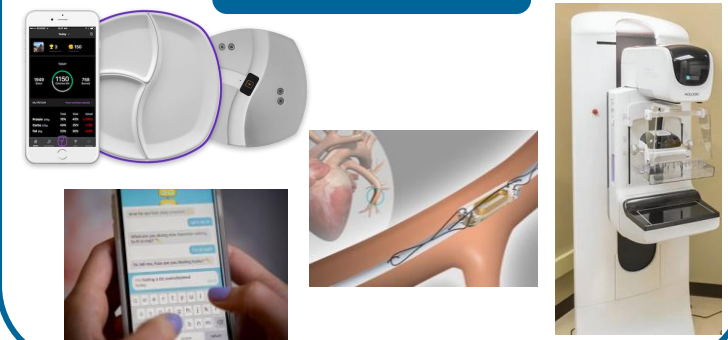
## "Spokes"



## "Add-ons"



## "Dreams"



- ❑ Anemia
- ❑ Bone density loss
- ❑ Eating problems & body dysmorphia
- ❑ Fever
- ❑ Heart damage
- ❑ Hemorrhage
- ❑ Immune suppression
- ❑ Lung fluid
- ❑ Lymphedema
- ❑ Premature menopause
- ❑ Skin changes
- ❑ Sudden weight gain or loss
- ❑ UTI's & bowel changes

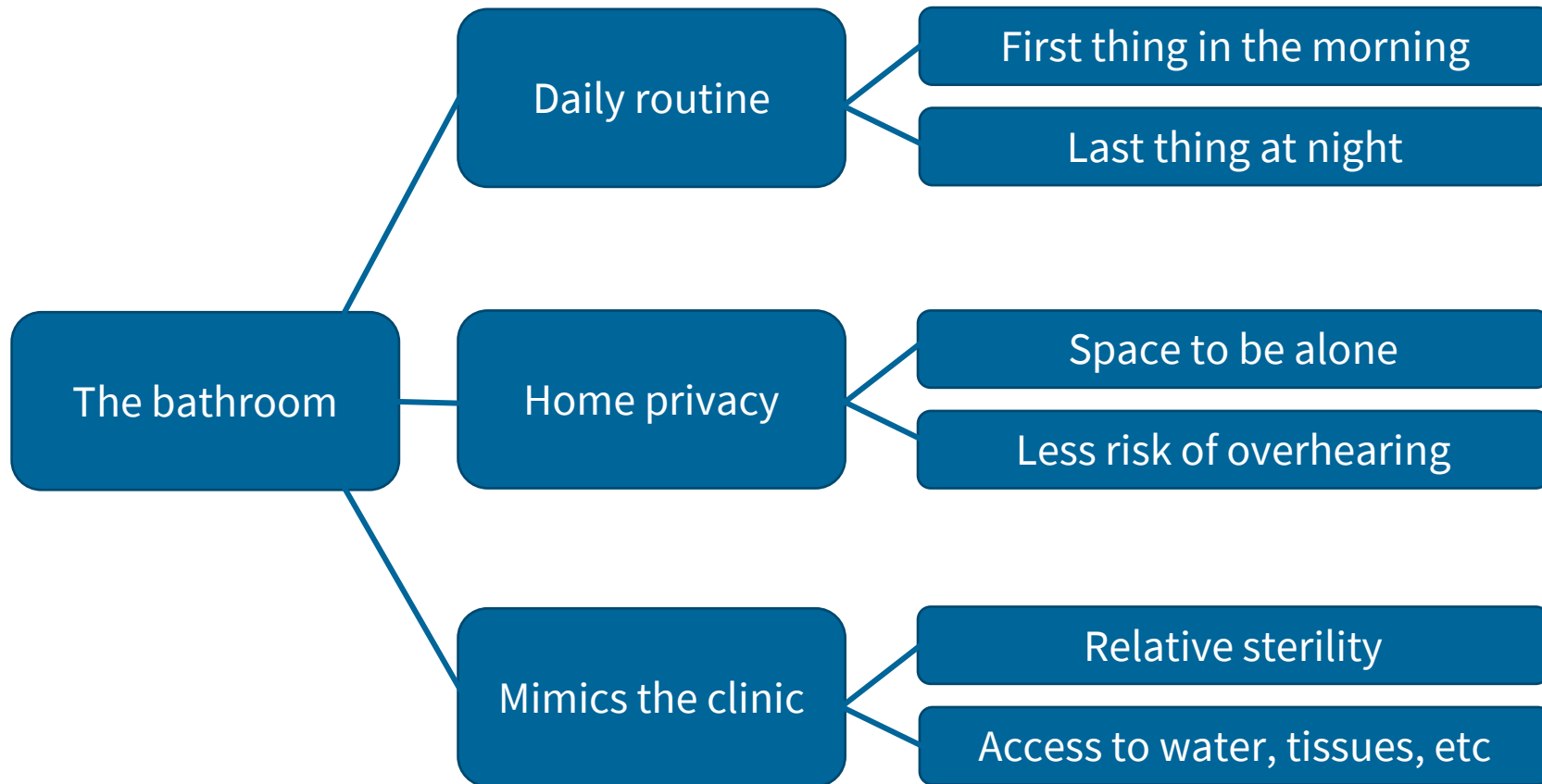
- ❑ Memory loss, nausea, fatigue, anxiety, pain, depression

- ❑ Relapse

- ❑ Melanoma
- ❑ Hodgkin lymphoma
- ❑ Breast cancer
- ❑ Prostate cancer
- ❑ Thyroid cancer

# Why the bathroom?

Ambience means tapping into human routine & culture



How do we respect bathroom privacy & build user trust?

## "EnLight system"

Integrated, Simple, Memorable

- Information collected; no further action required; on track
- Information still needs to be collected; action required
- Something went wrong; error; please try again
- Item is offline; no biometrics currently monitored



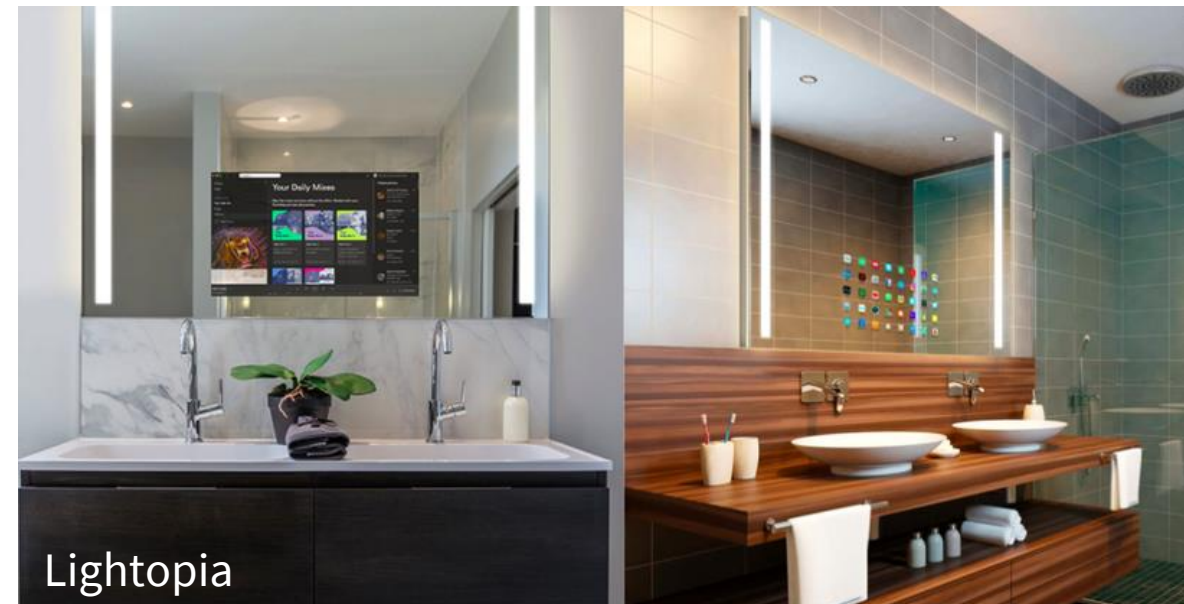
# The mirror: "Hub" to product "spokes"

The interface of our sci-fi dreams

## Mirror as an interface

- Smart wall
  - Technology: Lightopia (\$5000)
- User can view biometrics at a glance
  - Temperature, blood oxygen, weight, hydration, exercise, medication adherence, urine nitrite content
  - White blood cell count, neutrophil, lymphocyte, platelet counts
  - Test results (osteoporosis scans, dermatoscope results)
  - Biometrics over time
- Biometrics on screen during physician check-up

Black Mirror,  
episode  
"Nosedive"



Lightopia

# The mirror: User communication

Facilitating fluid conversation between START, the user, and MSK

Anemia, Bone density loss, Eating problems & body dysmorphia, Fever, Heart damage, Hemorrhage, Immune suppression, Lung fluid, Lymphedema, Premature menopause, Skin changes, Sudden weight gain or loss, UTI's & bowel changes, Memory loss, nausea, fatigue, anxiety, pain, depression



8:02 AM EnLight system

On a scale from 1 to 10, how are you feeling today?

Did you remember to take your estrogen pill today?

Let's get in a cardio workout this week!

3:22 PM

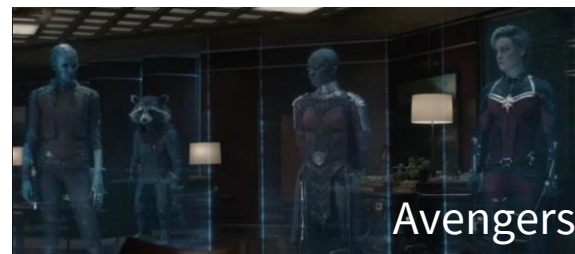
You have (1) new message from your provider. Would you like me to read it?

Your physician would like you to complete the Brief Symptoms Assessment (ESAS) form.

Would you like to complete it now?

## Wellness notifications

- Daily check-ins
- Natural language reminders



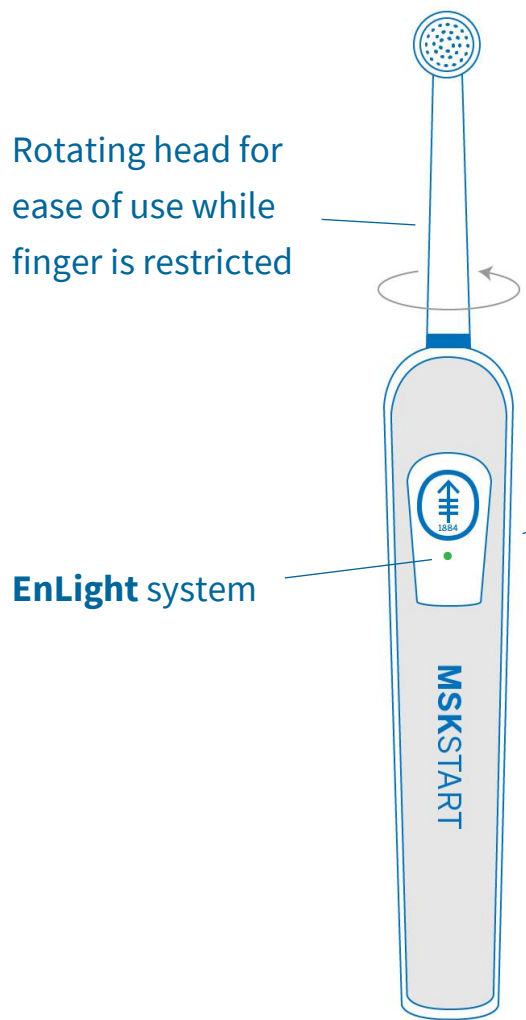
## Physician communication

- Virtual checkups ("hologram")
- Chatbot-facilitated queries & surveys

# The toothbrush

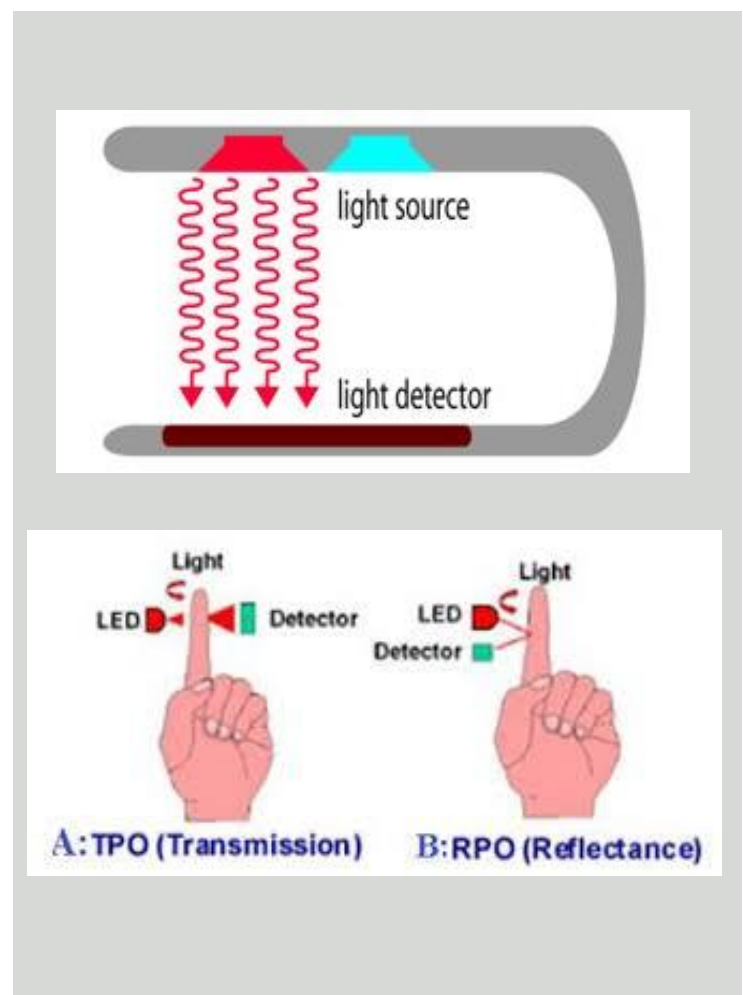
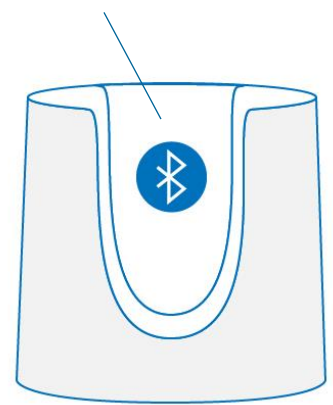
Ambient IR PulsOx & temperature tracking

Anemia, Bone density loss, Eating problems & body dysmorphia, Fever, Heart damage, Hemorrhage, Immune suppression, Lung fluid, Lymphedema, Premature menopause, Skin changes, Sudden weight gain or loss, UTI's & bowel changes, Memory loss, nausea, fatigue, anxiety, pain, depression



Dark chamber provides adequate atmosphere for **PulsOx** measurement. Finger provides pressure without clamp due to grip strength while brushing.

Docking station charges & protects toothbrush hardware while wirelessly transmitting PulsOx data

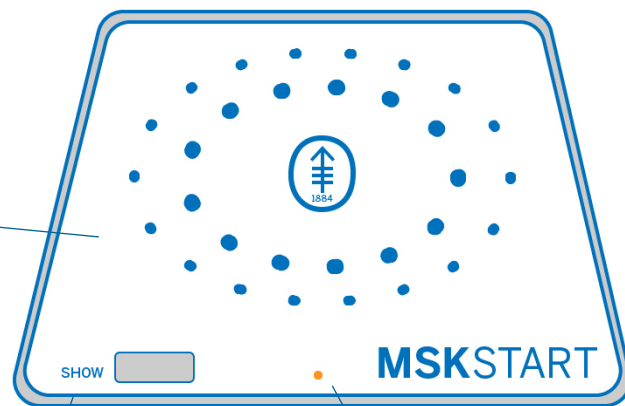


# The shower scale

Ambient weight tracking to alert cancer onset & relapse

Anemia, Bone density loss, Eating problems & body dysmorphia, Fever, Heart damage, Hemorrhage, Immune suppression, Lung fluid, Lymphedema, Premature menopause, Skin changes, Sudden weight gain or loss, UTI's & bowel changes, Memory loss, nausea, fatigue, anxiety, pain, depression

User stands on scale in the shower, which records most accurate **weight** value. This **porous silicon mat** covers shower drain, so chemotherapy patients with hair loss can also catch hair.



EnLight system

Show/hide weight feature prevents users from staring at their weight throughout shower, an action which promotes **body dysmorphia**

## Questionnaire:

1. Age (between 40 and 90 years) or Date of Birth  
Age:  Y:  M:  D:

2. Sex  Male  Female

3. Weight (kg)

4. Height (cm)

5. Previous Fracture  No  Yes

10. Secondary osteoporosis  No  Yes

11. Alcohol 3 or more units/day  No  Yes

12. Femoral neck BMD (g/cm<sup>2</sup>)  
Select BMD

This review of the literature indicates that weight gain is a common observation among women after the diagnosis of breast cancer. Gains in weight range from 0 to 50 lb and are influenced by menopausal status; nodal status; and the type, duration, and intensity of treatment. Weight gain appears to be greater among premenopausal women; among those who are node positive; and among those receiving higher dose, longer duration, and multiagent regimens. Psychosocial research suggests that weight gain has a profoundly negative impact on quality of life in patients with breast cancer. Recent findings also suggest that weight gain during therapy may

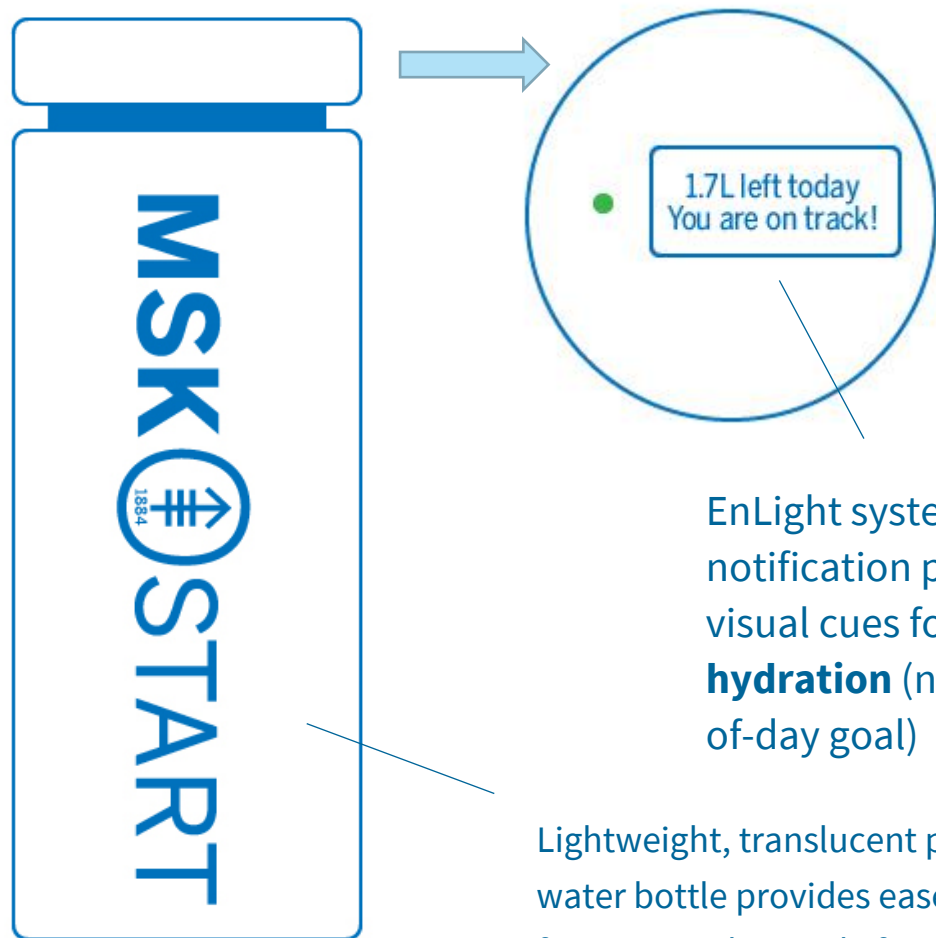
## Digital Weight Scale

Keep track of your patients' weight remotely with the 100Plus Digital Weight Scale. The smart scale enables practitioners like you to remotely monitor crucial changes in patient mass providing insights that are critical for patients with congestive heart failure or weight-related health issues like obesity. Stay connected to your patients' wellbeing with clear, continuous, and accurate data.

# The water bottle

## Ambient hydration tracking

Anemia, Bone density loss, Eating problems & body dysmorphia, Fever, Heart damage, Hemorrhage, Immune suppression, Lung fluid, Lymphedema, Premature menopause, Skin changes, Sudden weight gain or loss, UTI's & bowel changes, Memory loss, nausea, fatigue, anxiety, pain, depression



EnLight system & notification provides visual cues for **consistent hydration** (not just end-of-day goal)

Lightweight, translucent plastic water bottle provides ease of use for users with muscle fatigue

### Accuracy of daily fluid intake measurements using a “smart” water bottle

[Michael S. Borofsky](#), [Casey A. Dauw](#), [Nadya York](#), [Colin Terry](#) & [James E. Lingeman](#) ✉

measurements was 0.0% (95% CI – 3%, 3%). Intraclass correlation coefficient (ICC), calculated to assess consistency between hand measures and bottle measures, was 0.97 (0.95, 0.98) indicating an extremely high consistency between measures. 24-h fluid intake measurements from a novel fluid monitoring system (Hidrate Spark™) are accurate to within 3%. Such technology may be useful as a behavioral aide and/or research tool particularly among recurrent stone formers with low urinary volume.

**Dehydration is a common side effect of cancer treatment.**

**Chemotherapy and radiation treatment can cause dehydration due to other side effects, like fevers, vomiting, diarrhea or excessive urination.**

**These treatments can increase the need for IV hydration due to increased fluid needs.** Dehydration also can result from exposure to excessive heat, sweating, not consuming enough fluids, medication side effects or the cancer itself.

Source: MD Anderson

# The pill bottle

Ambient medication adherence tracking

Anemia, Bone density loss, Eating problems & body dysmorphia, Fever, Heart damage, Hemorrhage, Immune suppression, Lung fluid, Lymphedema, Premature menopause, Skin changes, Sudden weight gain or loss, UTI's & bowel changes, Memory loss, nausea, fatigue, anxiety, pain, depression

EnLight system



Auto-dispenser outputs multiple types of pills at regular daily times to promote **medication adherence** and medication uptake at a consistent time of day

## Study: AdhereTech's smart pill bottle intervention improves adherence without major additional expense

Conducted by AdhereTech and Avella Specialty Pharmacy, this is the first peer-reviewed study of adherence startup's eight-year history.



of the disease, has been proven untrue. Studies indicate the adherence rates for cancer therapy are 15% to 97%."

The ramifications for patients with cancer not properly following their regimens can be severe, warns Egerton. Non-adherence can lead to disease progression, additional physician visits, longer hospital stays, and increased mortality.

# The toilet sensor


## Ambient UTI tracking

Anemia, Bone density loss, Eating problems & body dysmorphia, Fever, Heart damage, Hemorrhage, Immune suppression, Lung fluid, Lymphedema, Premature menopause, Skin changes, Sudden weight gain or loss, UTI's & bowel changes, Memory loss, nausea, fatigue, anxiety, pain, depression

UTIs are one of the most frequent clinical bacterial infections in women, accounting for nearly 25% of all infections. Around 50–60% of women will experience a UTI in their lifetime.<sup>2,9</sup> The estimated number of UTIs per person per year is 0.5 in young females.<sup>12</sup> Recurrences usually occur within three months of the original infection, and 80% of RUTIs are reinfections.<sup>13</sup> The incidence of UTI increases with age and sexual activity.<sup>14</sup> Post-menopausal women have higher rates of UTIs because of pelvic prolapse, lack of oestrogen, loss of *lactobacilli* in the vaginal flora, increased periurethral colonisation by *Escherichia coli* (*E. coli*), and a higher incidence of medical illnesses such as diabetes mellitus (DM).<sup>15</sup> The microorganism

residential care facility. Multiple scientific studies have shown that Urinary Tract Infections (UTIs) are a leading cause of falls among the elderly – one study showing that 44% of patients admitted to a fall were suffering from a UTI. Detecting UTI's in older people can be difficult as a wide variety of

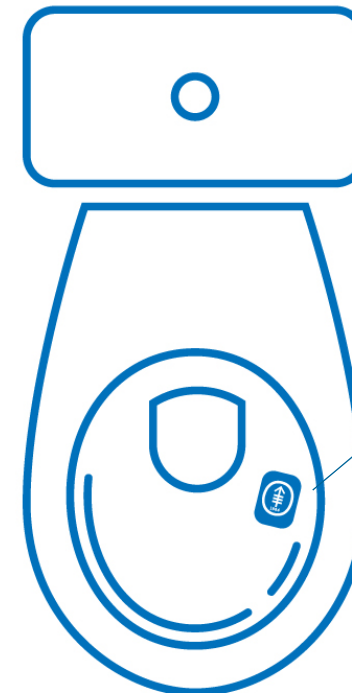
### 5. Conclusions

Go to: 

In conclusion, UTI are highly correlated with the incidence of all tumors. Clinicians should therefore refer to tumors screening in UTI patients, especially older patients, and not just patients with GUC. In UTI treatment, especially when multiple pathogenic factors are entailed, antibiotics must be used cautiously, and the time and dose of antibiotics should be minimized. Because UTI may increase the incidence of genital organ, bladder, kidney, male colorectal, prostate, and female liver cancer, knowledge about preventing UTI such as proper drinking water, exercise, and toilet habits should be enhanced in educating the general public.

## UTI TOILET SENSOR WINS ANALOG'S HACKATHON ON ASSISTED LIVING

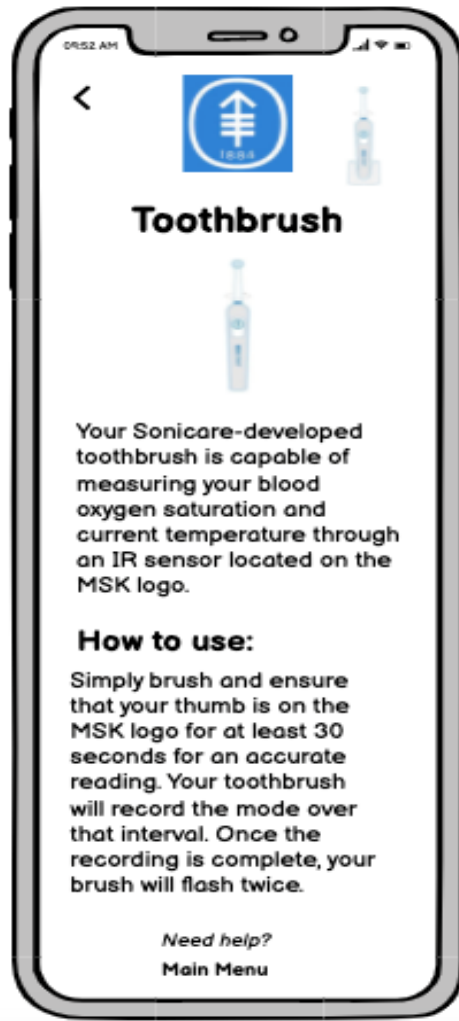
JOHN × NOVEMBER 15, 2017



Flush-washable UTI nitrite sensor detects time and urine characteristics

# Utilizing existing software: FitBit & phone app

Tracking wherever you go



## Fitbit

- Monitoring eating, sleeping, and activity levels.
- Fall detection based on change in vertical velocity with respect to ground and mechanoreceptors



MSK  START

**The add-ons:** Beyond the "wellness" package

# From a drop of blood

But not Theranos!

Anemia, Bone density loss, Eating problems & body dysmorphia, Fever, Heart damage, Hemorrhage, Immune suppression, Lung fluid, Lymphedema, Premature menopause, Skin changes, Sudden weight gain or loss, UTI's & bowel changes, Memory loss, nausea, fatigue, anxiety, pain, depression

- **Athelas, MIT**
  - Neutrophils, Lymphocytes, Platelets, White Blood Cell counts, all from a prick of blood



## What do the results mean?

Your health care team must carefully read CBC test results. Keep in mind that many factors, including noncancerous conditions, can lead to results that fall out of the normal range. Ask your doctor to help you understand what your results mean.

- **Low white blood cell count.** Some cancer treatments, mainly chemotherapy, may lower your body's white blood cells. Cancers that affect the blood and bone marrow can also lower the count. These types of cancers include leukemia, lymphoma, and multiple myeloma.
- **Amounts of different white blood cells.** Higher-than-normal numbers of lymphocytes or monocytes can indicate the possibility of certain types of cancers.

Some cancers and their treatments may cause **neutropenia**. Neutropenia is when a person has low numbers of neutrophils. This increases the chance of getting a bacterial **infection**. At times, your doctor may lower your chemotherapy dose to lower your chance of developing neutropenia. Your doctor may also recommend medication, such as white blood cell growth factors, to increase your body's production of neutrophils, especially if you develop a fever.

- **Low red blood cell count.** Some cancer treatments, mainly chemotherapy and radiation therapy, may lower your red blood cells count. This condition is known as **anemia**. Blood loss, either from surgery or specific cancers, and cancers that directly involve the bone marrow can also cause or worsen anemia. People whose red blood cell count falls too low may need a blood transfusion or medication to help bring it up.
- **Low platelet count.** Some cancer treatments, such as chemotherapy or radiation therapy, may cause a decrease in platelets. Cancers that directly involve the bone marrow can also lower the platelet count. An unusually low number of platelets is called **thrombocytopenia**. People with low platelet levels have a greater risk of serious bleeding or bruising. If your platelet count falls to very low levels, your doctor may recommend platelet transfusions.

# Dermatoscope at your fingertips

Magnifying the power of your phone camera

Anemia, Bone density loss, Eating problems & body dysmorphia, Fever, Heart damage, Hemorrhage, Immune suppression, Lung fluid, Lymphedema, Premature menopause, **Skin changes**, Sudden weight gain or loss, UTI's & bowel changes, Memory loss, nausea, fatigue, anxiety, pain, depression



Dermatoscope useful for skin melanomas and mole anomalies.



Simply take a picture or snapshot of the skin melanoma for diagnosis.



External magnifier attachment for at-home analysis of skin anomalies. If phone cameras can be made this powerful (light source, magnifier, liquid medium), snapshots can be sent to dermatologists for quick and rapid analysis.



High resolution images and accurate diagnosis/treatment/progression.

# Ultrasounds at home




Not as far away as you might think

Anemia, Bone density loss, Eating problems & body dysmorphia, Fever, Heart damage, Hemorrhage, Immune suppression, Lung fluid, Lymphedema, **Premature menopause**, Skin changes, Sudden weight gain or loss, UTI's & bowel changes, Memory loss, nausea, fatigue, anxiety, **pain**, depression

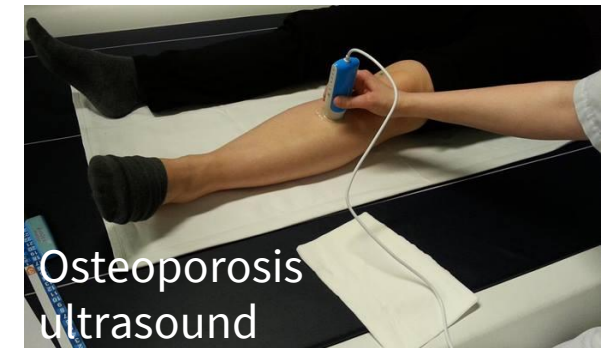
- Peripheral **osteoporosis** scans
  - pDXA (peripheral dual energy X-ray absorptiometry)
  - QUS (quantitative ultrasound)
  - pQCT (peripheral quantitative computed tomography)
- Ultrasounds accompany **mammograms**

On the market for \$1,690



		
LG Pro Series Ultrasound Unit	US Pro 2000 2nd Edition Portable Ultrasound ... ★★★★★ (179)	US 1000 3rd Edition Portable Ultrasound Compare prices from 10+ stores ★★★★★ (150)
\$209.99 LGMedSupply.com	\$149.95 TENSPros	\$43.66 Healthy You

Pain relief  
ultrasounds

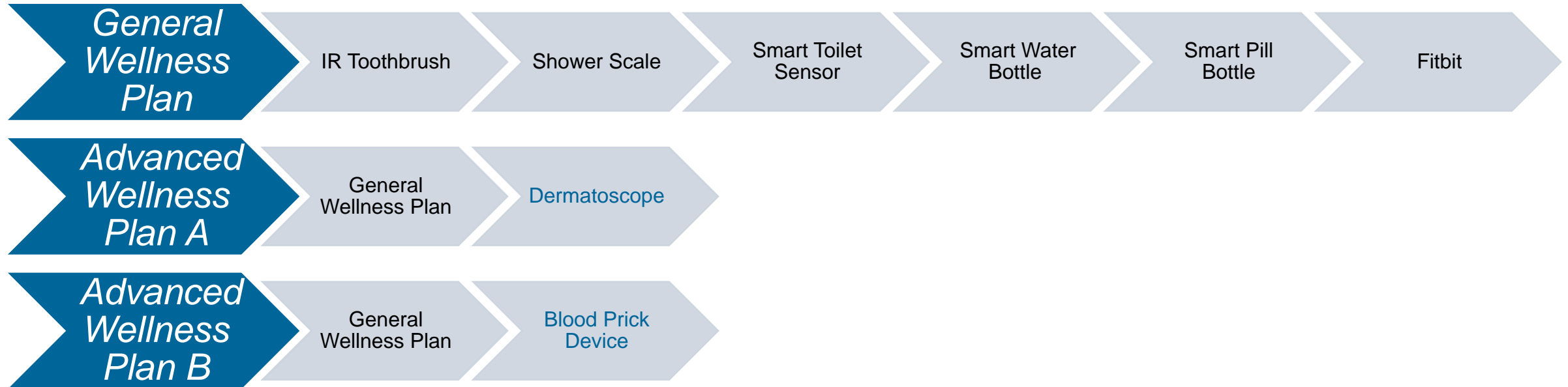




**The model:** What plans can we offer patients?

# Patient Plans by **MSK** **START**

All plans include our state-of-the-art mirror!



# In the eyes of Sarah: Pre-treatment

How does MSK START touch the individual?

Sarah is a 45-year-old woman who works in the HR department at a large supply firm in NYC. She has a husband and two kids. She has recently been diagnosed with **breast cancer** last February.

Normally, it would be easy for her to come into MSK to get treatment. However, because of COVID-19 she finds it **difficult and unsafe to see her provider.**

## How can MSK START help?

- **Direct messaging** on the mirror allows her constant access to MSK's knowledge base and clinicians
- **Emotional check-ups** from the mirror can help providers detect abnormal stress trends and direct her to appropriate resources
- Sarah receives **daily reminders** about medication, exercise, hydration, and sleep
- Constant **weight monitoring** with the shower mat tracks tumor growth symptoms
- IR toothbrush allows her to measure her **temperature** and **blood oxygen** constantly to detect serious fevers or infections (COVID-19)

# In the eyes of Sarah: During treatment

How does MSK START touch the individual?

Sarah is started undergoing her **chemotherapy** journey in March. Sarah is **immunocompromised** and worried about her possibilities of developing other illnesses and infections, including those brought on by UTI's, fevers, and dehydration. Sarah is a little **overwhelmed by the amount of medication** she needs to remember to take. She wants to know her **complete blood cell count** so she can monitor her immune system.

## How can MSK START help?

- As chemotherapy causes dehydration, Sarah's **smart water bottle** continually reminds her to stay on track with drinking water
- Sarah's **smart pill bottle** makes taking the right pills on the right days a breeze
- Sarah's **IR toothbrush** tracks fever-inducing infections and respiratory illness (COVID-19), which her immune system may not be able to handle
- Sarah's **smart toilet** tracks UTI's days in advance, so she can use antibiotics before things get serious
- Our **blood-pricking add-on** allows regular CBCC updates to her physician, and she can **message** and speak with her physician through the mirror



# In the eyes of Sarah: After treatment

How does MSK START touch the individual?

Sarah is finally **in remission** this June – woohoo! Her MSK oncologists would still like to track her **temperature, weight gain/loss, bone density loss, and emotional wellbeing** through both physical tests and **surveys**. Other biometrics will also help inform them whether Sarah is under any risk of relapse.

## How can MSK START help?

- Sarah's **IR toothbrush** tracks fever-inducing infections and respiratory illness (COVID-19), which her immune system may not be able to handle
- Constant **weight monitoring** with the shower mat tracks tumor growth symptoms
- **Emotional check-ups** from the mirror can help providers detect abnormal stress trends and direct her to appropriate resources
- **Physician message reminders** makes sure Sarah doesn't miss any of her doctor's orders
- **Verbal survey completion** via the mirror makes user engagement a breeze for Sarah

MSK  START

**The dreams:** In a galaxy far, far away...

# Food scanner

Optimizing nutrition via daily plate tracking & genetics

Anemia, Bone density loss, Eating problems & body dysmorphia, Fever, Heart damage, Hemorrhage, Immune suppression, Lung fluid, Lymphedema, Premature menopause, Skin changes, Sudden weight gain or loss, UTI's & bowel changes, Memory loss, nausea, fatigue, anxiety, pain, depression



Tracking food intake is one of the most effective ways to enforce new eating habits. Using Smart Plate's portable plate and app, you can accurately analyze and log what you're eating in seconds with Food Recognition Technology. Its AI tracks the calories, carbs, fat, fiber, sugar and sodium in your entire meal. All you have to do is take a photo of it.

WELLNESS

## Personalized Nutrition: The Latest on DNA-Based Diets

What can our genes tell us about which diet will work best for us?

If these differences are genetically driven, then we would expect the identical twins to respond similarly. But they didn't. Genetics appeared to account for less than a third of the subjects' insulin and triglyceride responses. The specific ratio of fats and carbohydrates in the diet were also not strongly predictive. Other factors, such as sleep habits, exercise, stress, and gut microbes appeared to play a much bigger role in our individual responses to diet.

This is bad news for companies who are selling DNA-based diets. But it's good news for you and me. We can't change our genes. But we can change how much we sleep, how we manage stress, and how much we exercise. We can even influence our gut microbes.

# Emotional monitoring

Facial scans, voice monitoring, social media monitoring

Anemia, Bone density loss, Eating problems & body dysmorphia, Fever, Heart damage, Hemorrhage, Immune suppression, Lung fluid, Lymphedema, Premature menopause, Skin changes, Sudden weight gain or loss, UTI's & bowel changes, Memory loss, nausea, fatigue, anxiety, pain, depression

**66%** of patients undergoing chemotherapy are affected by the symptoms of **depression**.

- Diagnosing depression through **chatbots**
  - Woebot and Cognitive Behavioral Therapy
- Diagnosing depression through **vocal timber**
  - Ambient language pickup (from morning conversation with mirror?)
- Diagnosing depression through **facial scans**
- Diagnosing depression through **social media or phone activity**

Sound mind: Detecting depression through voice

*Computing science researchers improve technology for identifying depression through vocal cues*

UNIVERSITY OF ALBERTA

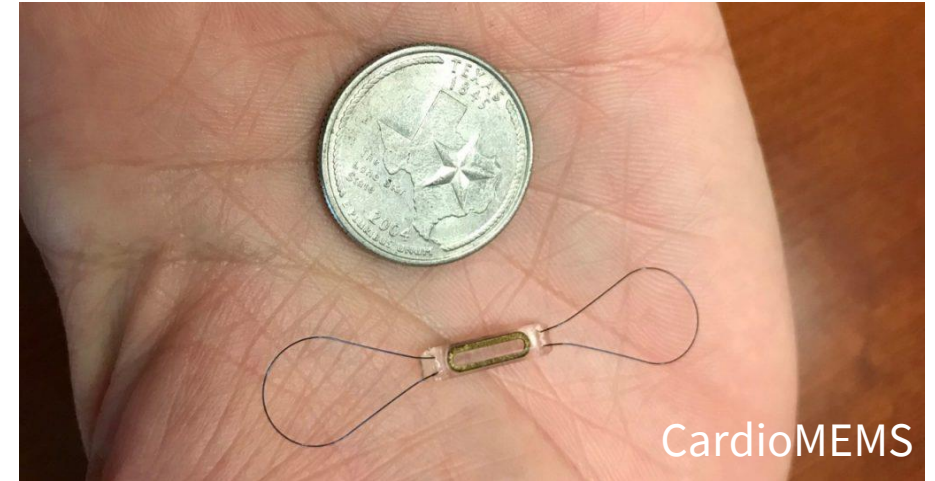


# X-rays and implants

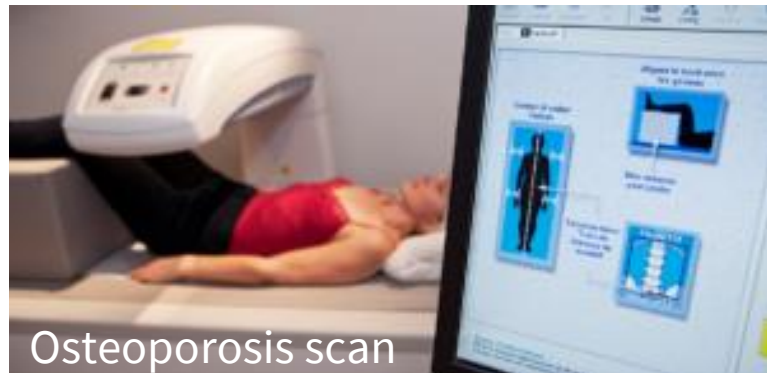
The very, very far future

Anemia, Bone density loss, Eating problems & body dysmorphia, Fever, Heart damage, Hemorrhage, Immune suppression, Lung fluid, Lymphedema, Premature menopause, Skin changes, Sudden weight gain or loss, UTI's & bowel changes, Memory loss, nausea, fatigue, anxiety, pain, depression

- Portable, low-radiation x-rays ("**tricorder**")
  - Ultrasounds, mammograms
- Implant support in the mirror
  - **CardioMEMS**, FDA-approved heart health tracker
  - Estrogen, progesterone hormone trackers
  - Thyroglobulin tracker
  - Birth-control style implant treatment?



Springfield. "It is too late in the game when we wait for the patient's fluid buildup to be detected by a three-pound weight increase or by a change in how congested they feel. This device detects changes a few days to a week before you see it on the scale."



- **Your thyroglobulin levels are high and/or have increased over time.** This may mean thyroid cancer cells are growing, and/or cancer is starting to spread.
- **Little or no thyroglobulin was found.** This may mean that your cancer treatment has worked to remove all thyroid cells from your body.
- **Your thyroglobulin levels decreased for a few weeks after treatment, but then started to increase over time.** This may mean your cancer has come back after you've been successfully treated.

# But we know it's not that easy

How far away are our dreams?

## Will users trust us?

- How do we build trust in users to let MSK into their most private spaces? (EnLight system?)
- The "Alexa" problem

## What should patients see?

- Do patients have a right to know everything about their bodies? What info should we withhold?
- How do we ensure users correctly interpret data?

## Who handles the clinician side?

- What kind of infrastructure or cultural shift do we need on MSK's end?

## What about portability?

- What happens when the user leaves the ambient space? Should we rely so much on location?

## Did we forget accessibility?

- How do we ensure that health tech is not something that increases existing disparities in standard of care?

MSK  START

Symptoms Tracking at Real Time

# Appendix



# Remote monitoring stats



## Research

The current consumer demand for health monitoring in the home:



**23%** of 55-64 year olds would be less stressed if their home could help with their healthcare



**76%** are worried about their elderly relatives living alone, with **41%** most worried about them suffering an emergency such as a heart attack or fall



**42%** of 35-44 year olds are worried about their relatives not telling anyone if they feel ill



## Research

**36%** have waited up to a week for a GP appointment, **29%** have waited up to 2 weeks

**17%** of 18-24 year olds have waited **5 weeks** for a GP appointment

**20%** of 35-44 year olds have waited **3 weeks** or more for an appointment

Females are most concerned about the length of time they have to wait for an appointment (**44%**)

**18-24 year olds** are the age group most likely not to go to the doctor if they don't know or are embarrassed about their symptoms

**25-34 year olds** are most concerned out of all the age brackets about the appointment time wait, with **47%** putting them off going to see the doctor

# Other implants

## Example devices

- Detects heart rhythm changes, device malfunction and fluid retention in the lungs
  - The **OptiVol** Fluid Status Monitoring, found on **Medtronic** cardiac resynchronization therapy-defibrillators (CRT-Ds) and implantable cardioverter-defibrillators (ICDs), can detect fluid build-up in the chest, a common symptom of heart failure. Some systems also offer options to connect a weight scale and blood pressure monitor to the base unit so the information can be transmitted remotely.
  - In 2001 **Biotronik** was the first company with an FDA-approved wireless, remote monitoring system – Home Monitoring. Medtronic followed in 2005 with **CareLink**, Boston Scientific in 2006 with **Latitude**, and St. Jude in 2007 with **House Call**.
  - St. Jude Medical's **Confirm**, Medtronic's **Reveal XT** and Transoma Medical's **SLEUTH AT** are recently FDA-cleared ICMs.

# Efficacy of implants on hospital care

The **Cleveland Clinic** conducted a study in 2008, which showed an increasing number of patient evaluations can be managed without directly increasing demands on clinic staff time and resources. The study tracked ongoing ICD device follow-up patient visits over a four-year period. Using Web-based data transmissions, the clinic said it was able to better manage time and overall utilization of in-clinic resources. During the study, **remote evaluations increased from 94 to more than 5,000 patients without adding additional staff**. Just for patients with defibrillators, the clinic had 7,000 scheduled appointments per year. Today the Cleveland Clinic says it remotely monitors 5,000 of those patients, which includes about 12,000 remote checks.

Same goal as Josie Robertson! (no additional physical space but lots of additional capacity)

# Symptoms recorded by CardioMEMS

Table 1

Remote PM monitoring: event notifications.

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**Pacemaker and leads: integrity and functioning of the implanted device**

- Battery condition: depletion condition and impedance measurements; elective replacement indicator
- Pacing or shock lead condition: impedance and its changes
- Automated pacing threshold measurement
- Automated sensing threshold measurement
- Detection of interference interrupting correct device functioning

**For ICD: arrhythmias episode diagnostics, shock effectiveness**

- Diagnostic features of the device recipient
  - Incidence, duration, onset and offset of atrial and ventricular arrhythmic events, mode switching for atrial tachycardia and other arrhythmic events
  - Survey of daily heart rate: to determine the medication effects, pacing rate, pattern of rate response pacing
  - Atrial/ventricular pacing percentage, see CRT
  - Vital signs: including daily activity pattern, heart rate variability and intrathoracic impedance as a measure of pulmonary capillary wedge pressure
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