

C3CLOUD

A FEDERATED COLLABORATIVE CARE AND CURE CLOUD
ARCHITECTURE FOR ADDRESSING THE NEEDS OF MULTI-
MORBIDITY AND MANAGING POLY-PHARMACY

Addressing the Needs of Multi-morbidity through Digitally Enhanced Integrated Care: The C3-Cloud H2020 project

Theodoros N. Arvanitis, RT, DPhil, CEng, FRSM, FGBHI
Chair in Digital Health Innovation & Director of the Institute of Digital Healthcare



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 689181



SETTING THE SCENE



People living with multimorbidity:



are at greater risk of negative outcomes such as increased mortality, lower quality of life, and greater use of healthcare services, including unplanned admission to care settings.



face challenges in navigating the health and care system and managing their health and are generally less satisfied with the care they receive.

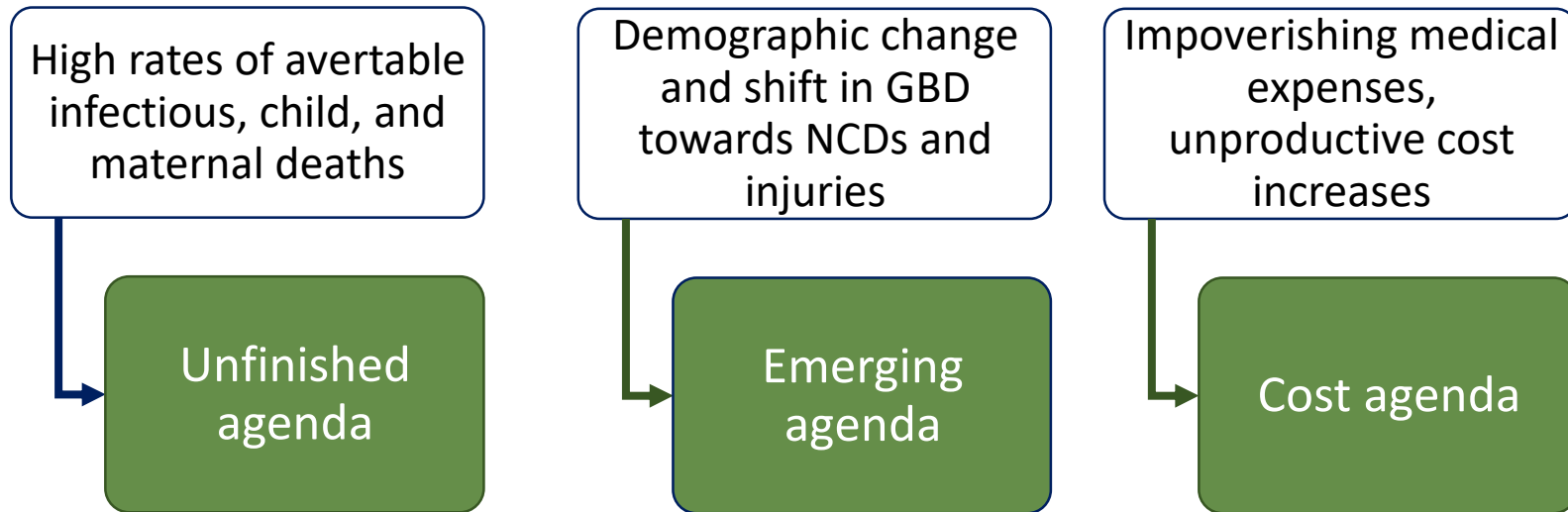


experience too much emphasis on their conditions, and not enough emphasis on how these conditions affect them.



see little attention on the wider determinants of health and how these impact on their lives and outcomes.

2015-2035: THREE DOMAINS OF HEALTH CHALLENGES



Source: The Commission on Investing in Health

THE LANCET GLOBAL HEALTH 2035



MULTIMORBIDITY IN THE CONTEXT OF C3-CLOUD

- Accumulation of multiple chronic conditions, including a growing number of functional and cognitive impairments
- Currently, around 50 million European citizens suffer from two or more chronic conditions
 - More than 50% of all older people have *at least 3 chronic conditions*, and a significant proportion *has 5 or more*.
- Multimorbidity is also relating to newly observed trends of older people in the EU, as being identified as more likely than average to be obese
- Multimorbidity can also refer to:
 - disability
 - acute conditions
 - or more severe conditions that are more sudden in onset than chronic diseases, eg a cancer diagnosis
 - have increased vulnerability or decreasing resilience to seemingly cope with minor health events, e.g. infection or medication changes
- **Multidimensional view**, taking into account social and environmental as well as physical and psychological factors

CHALLENGES OF MULTIMORBIDITY



Clinicians' knowledge is insufficient for assessment of multimorbidity – particularly in terms of **care and support planning**.



The current model of health and 'traditional way of doing things' acts as a barrier to client and family participation and involvement in **shared decision-making**.



Much of the health and care system and workforce is designed to respond to a **single disease** rather than multiple ones



Movement towards **self-management and social prescribing** for achievement of medium to long term outcomes is inhibited by single disease focus.

DIGITALLY ENHANCED INTEGRATED CARE

- At present, it is suggested that there is no 'single model' that can be applied universally to achieve care services for people with complex needs.
- **Integrated Care**
 - The management and delivery of health services so that citizens receive a continuum of preventive and curative services,
 - according to their needs over time
 - and across different levels of the health system
 - Can potentially provide such a co-ordinated approach.
- Digitally-enabled approaches can provide more adaptive and radical solutions to the provision of integrated care.
- C3-Cloud: a software-intensive sociotechnical system for integrated care

PROJECT INFORMATION



➤ A Federated Collaborative Care and Cure Cloud Architecture for Addressing the Needs of Multi-morbidity and Managing Poly-pharmacy

- H2020 RIA project
- Dates: May 2016 – April 2020
- Total budget: €4.9 million
- Coordinator: University of Warwick, UK
- 12 partners from 7 European countries

➤ Pilot sites:

- Region Jamtland Härjedalen, Sweden
- South Warwickshire NHS Foundation Trust, UK
- Servicio Vasco de Salud - Osakidetza, Spain

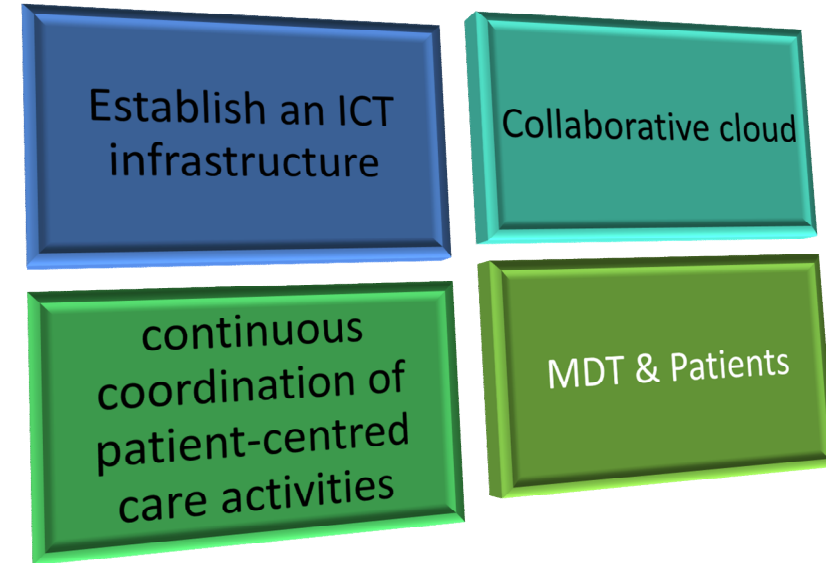


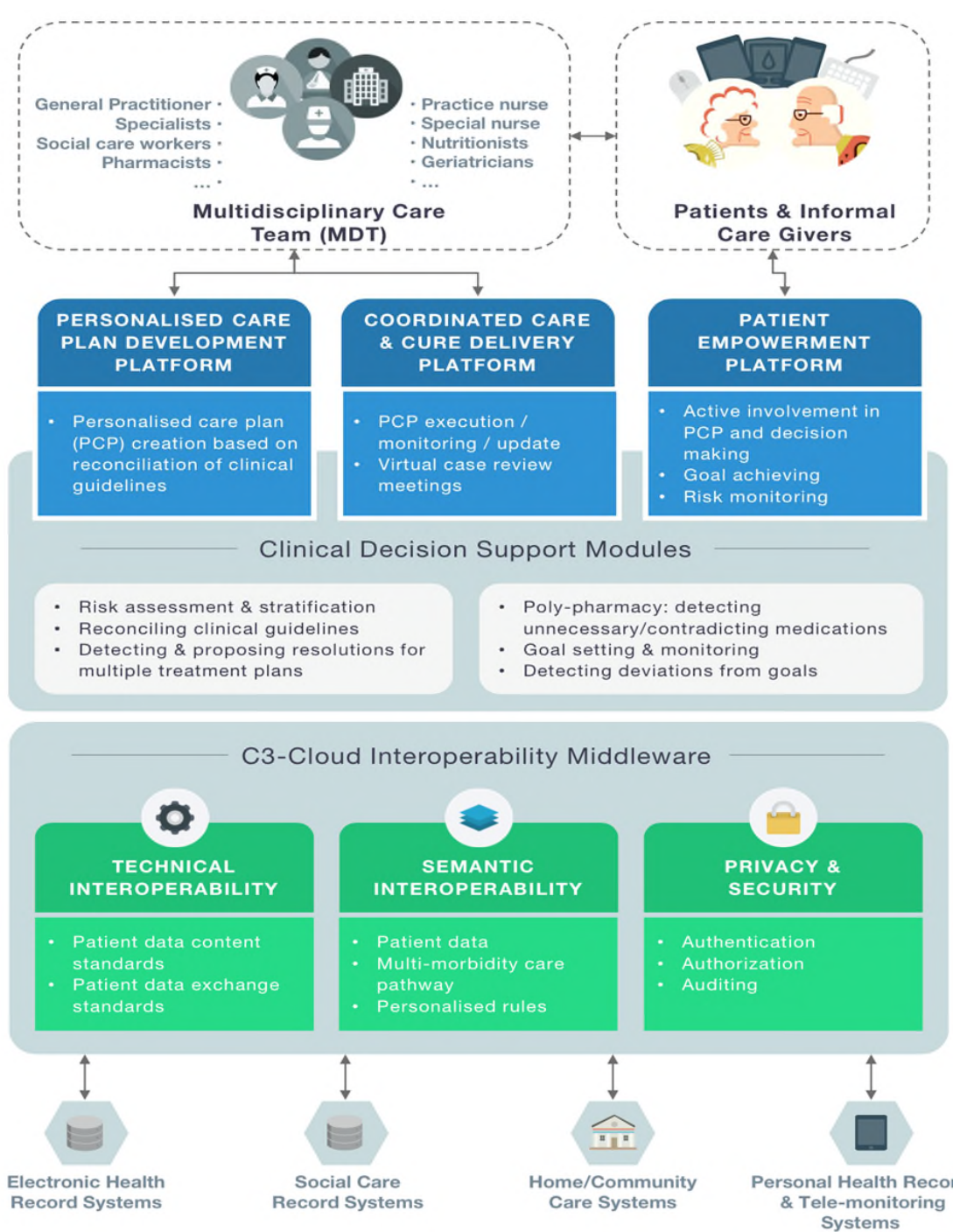
C3-CLOUD OBJECTIVES



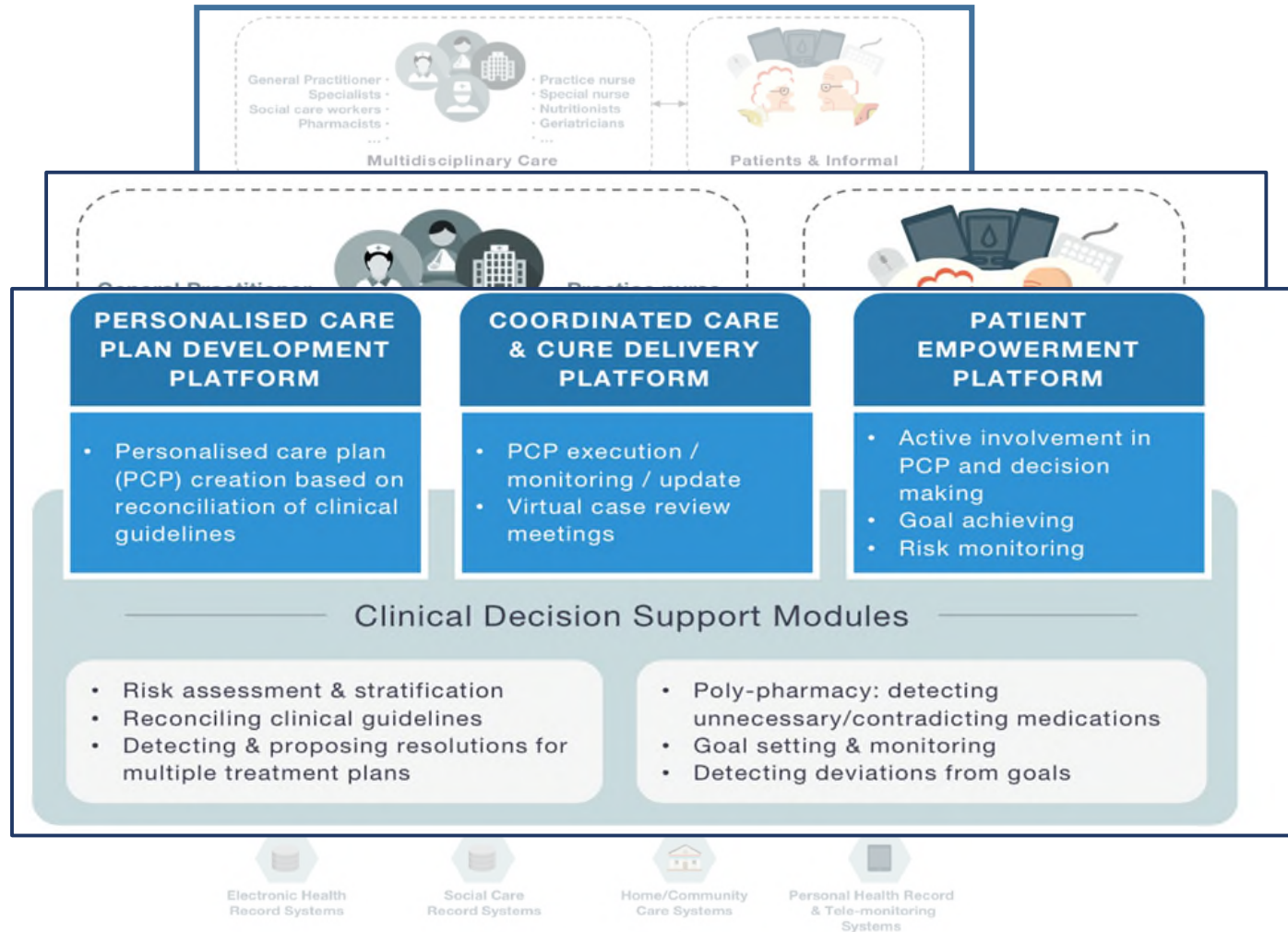
- **Collaborative creation and execution of personalised care plans** for multi-morbid patients through systematic and semi-automatic reconciliation of clinical guidelines.
- **Decision Support** for risk prediction and stratification, recommendation reconciliation, poly-pharmacy management and goal setting.
- **Fusion of multimodal patient and provider data.**
- **Integrated Terminology Server** with advanced semantic functions will enable meaningful analysis of multimodal data and clinical rules.
- **Active patient involvement** and treatment adherence evaluation.

To demonstrate feasibility, pilot studies will focus on diabetes, heart failure, renal failure, depression in different **comorbidity combinations**. (3 European regions)

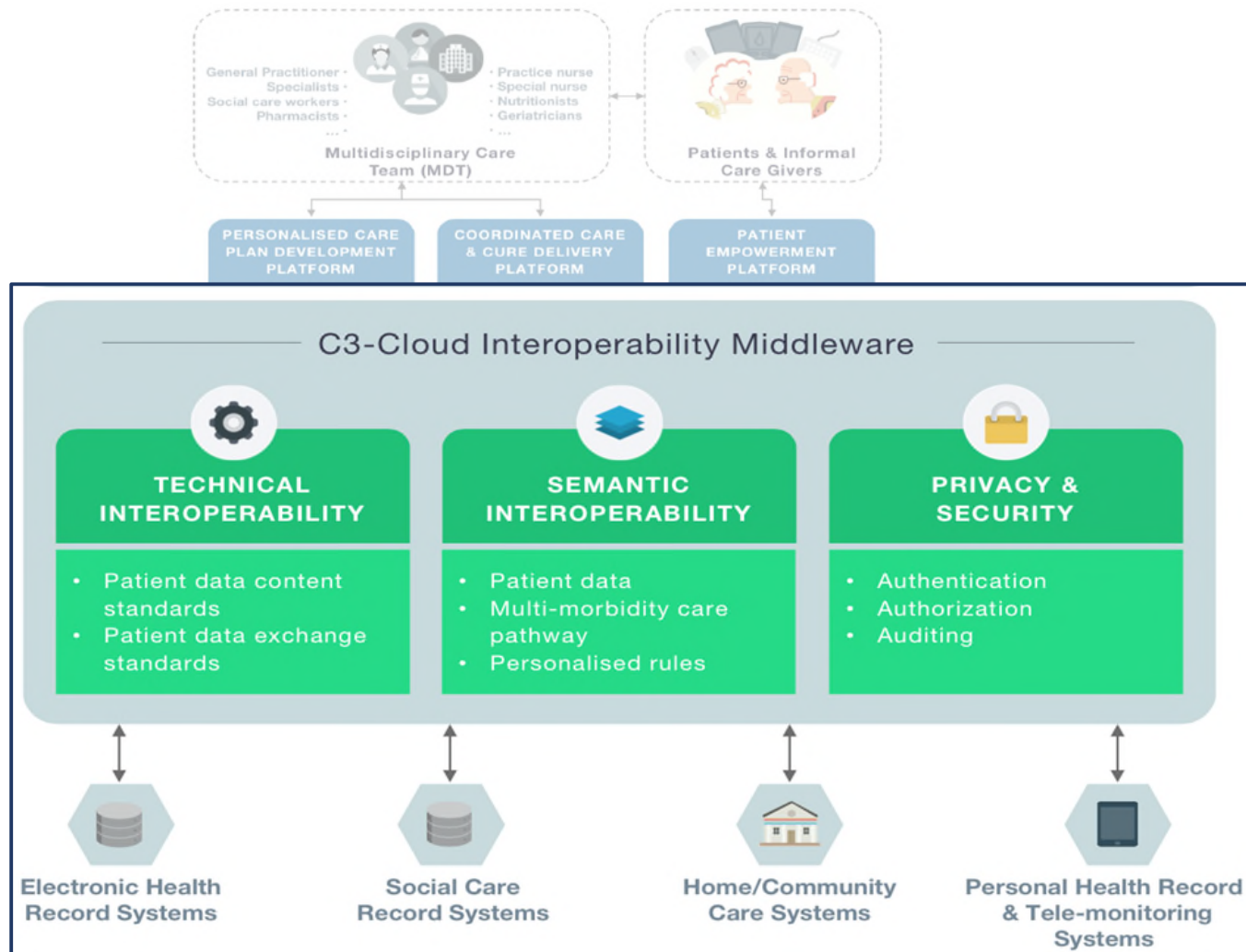




The C3 Cloud Architecture



The C3 Cloud Architecture



The C3 Cloud Architecture

DIGITALLY-ENHANCED AND SOFTWARE INTENSIVE TOOLS IN C3-CLOUD



Specific Challenges

- Managing multimorbidity without **informed involvement** of all stakeholders, resulting in **specialty silos and fragmented care**
- Existing organisational models and care pathways are inadequate for integrated care delivery

C3-Cloud Objectives

- Enable **MDT members** to **collaboratively** manage integrated care plans, and support them to provide the best possible care
- **Seamlessly integrate** with the existing health and social care information systems

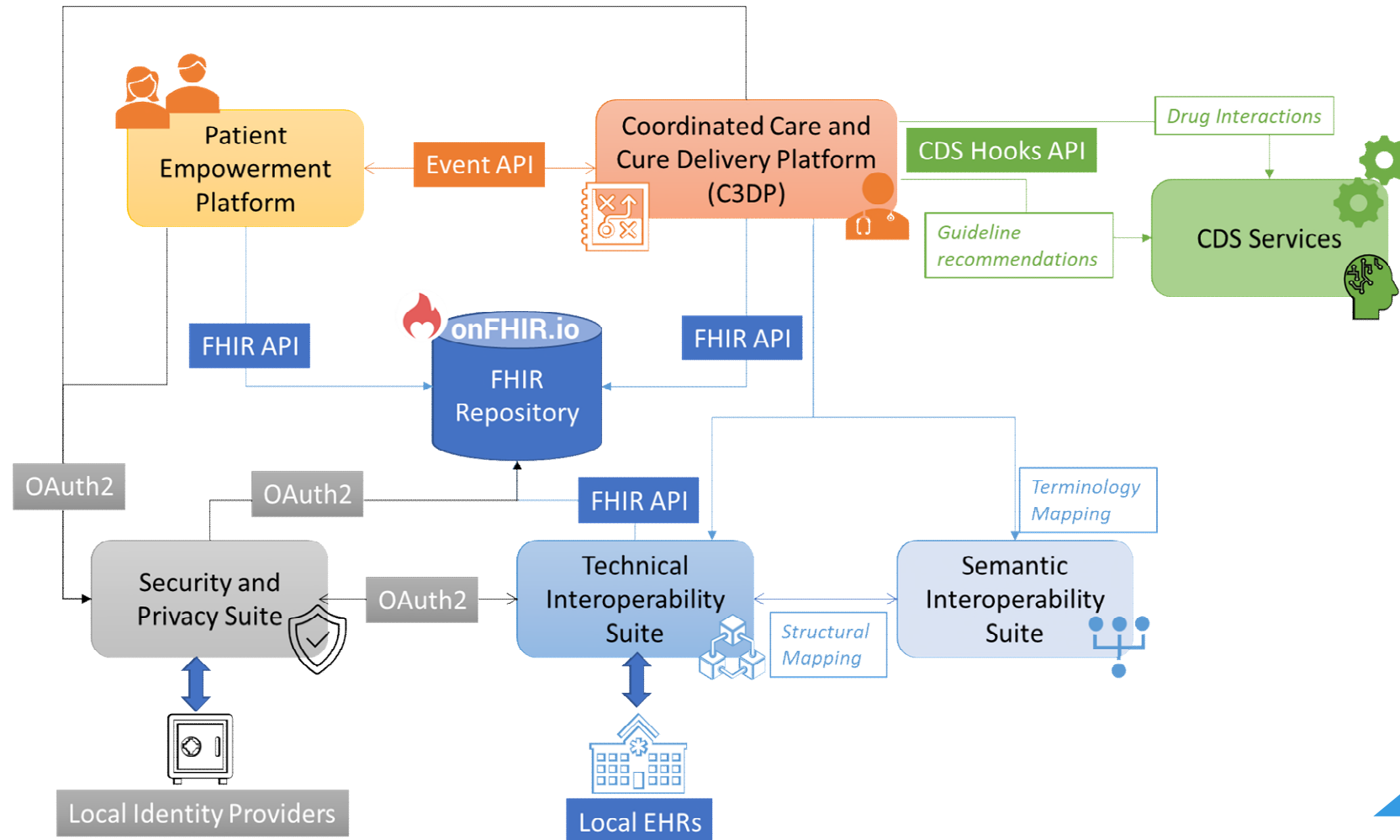
C3-Cloud Results

- C3-Cloud integrated care approach and ICT tools is **an end-to-end solution** for integrated care delivery
- **Optimisation** of multi-morbidity care pathways and organisational models based on the assessment of the pilot applications

Integrated Care Delivery End-to-end Solution

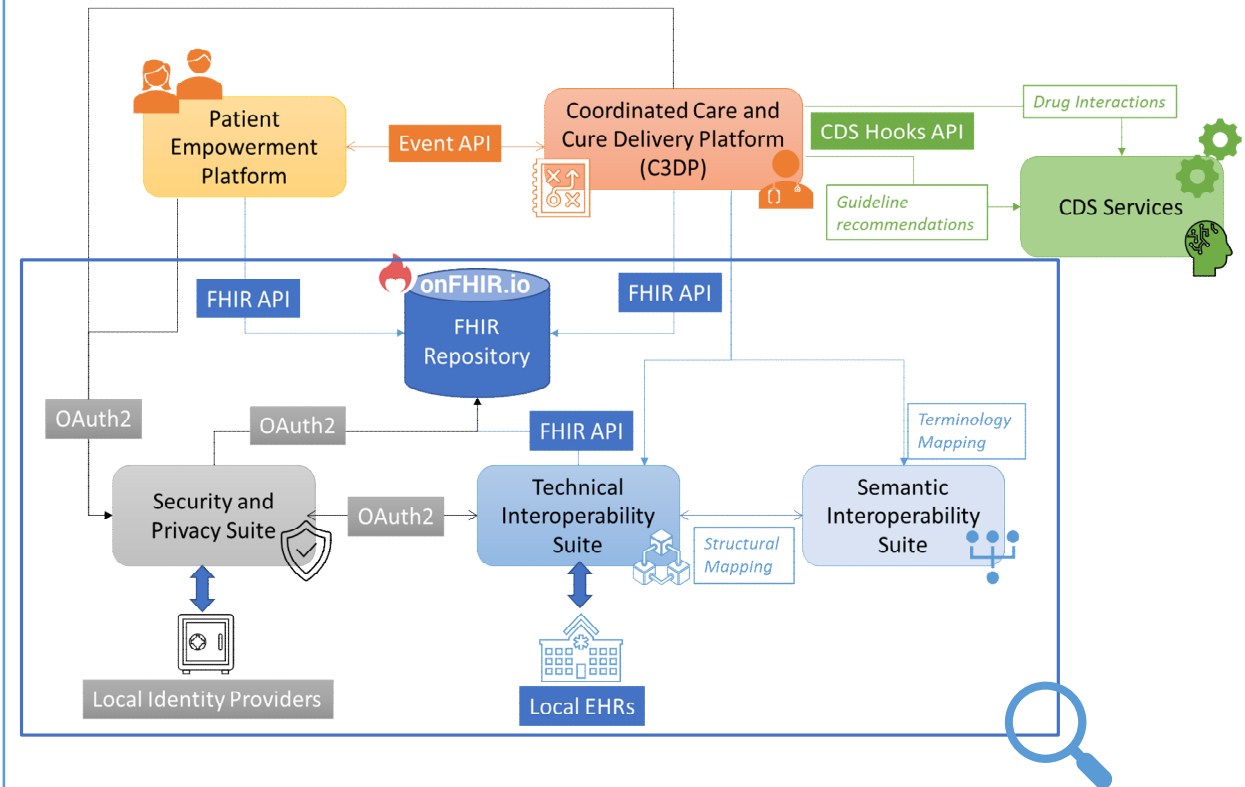
C3-Cloud Integrated Care Coordination Design

- Identification of stakeholder needs using scenarios for the 3 pilot sites
- 60 Pilot application requirements identified
- 348 technical requirements identified for 6 components of the system
- Survey of the latest technologies, standards, architectures



C3-Cloud Interoperability Layer

- HL7 FHIR has been chosen as the common model
- C3-Cloud's common shared repository is a secure, scalable **FHIR Repository**
- **Technical Interoperability Suite (TIS)**
 - Enables data exchange between the local EHR systems of the pilot sites and the C3-Cloud components via FHIR Repository
- **Semantic Interoperability Suite (SIS)**
 - Structural transformation from local EHR formats to HL7 FHIR & Terminology mapping
- **Security and Privacy Suite (SPS)**
 - Care Team Member authentication and authorization
 - Implements OAuth 2.0, OpenID Connect 1.0 and Smart App Authorization specifications
 - Integration with pilot site IdP systems (e.g. MS ADFS)
 - Audit Record Repository



Online Platform for the Management of Integrated Care Plans by MDT

- Review of medical summary
- Cross-check of all patient data needed as input by the CDS services
- Management of the care plan building blocks; goals, activities and education materials
 - Manual entry from scratch
 - Recommendations from the CDS services
- “Execution” of a care plan
 - Updating the progress of goals and activities
 - Re-execution of CDS services during planned and unplanned encounters
 - Display of patient provided data
 - Commenting on the care plan items
- Management of the care team
- Communication among care team and patient/informal care giver
- Dashboard view
- Patient provided data screen
- Activity calendar
- Real-time system notifications

The screenshot displays the KronIQ web application interface. On the left is a patient profile for Ahmet Kılıç, including contact and address information. The main area is divided into 'Goals' and 'Activities' sections. The 'Goals' table lists two targets: HbA1c < 46 mmol/mol and Blood pressure panel (Systolic < 130 mmHg, Diastolic < 90 mmHg). The 'Activities' table lists various tasks such as appointments, follow-ups, questionnaires, diet, patient orders, lab requests, and medication prescriptions.

Title	Start Date	Target Date	Target	Actions
Treatment target is supposed to be 46 mmol/mol (< 4.4%)	25 May 2020	25 Aug 2020	HbA1c < 46 mmol/mol	[-]
Keep blood pressure under control	25 May 2020	25 Aug 2020	Blood pressure panel Systolic Blood Pressure < 130 mmHg Diastolic Blood Pressure < 90 mmHg	[-]

Title	Type	Start Date	Actions
GP Appointment for management of nephropathy	Appointment	25 May 2021	[-]
Follow-up to check the results of the treatment	Appointment	06 Jul 2020	[-]
NA - Self-Efficacy for Diabetes	Questionnaire (Repeating)	25 May 2020	[-]
Mediterranean diet with reduced sodium level (salt intake)	IT Diet	25 May 2020	[-]
Self-measurement of blood pressure	Patient Order	25 May 2020	[-]
Self-monitoring of Blood Glucose	Patient Order (Repeating)	25 May 2020	[-]
HbA1c Test	Lab Request	05 Jun 2020	[-]
Prescribe DPP4 inhibitor	Medication	25 May 2020	[-]
Acetylsalicylic acid	Medication	10 Nov 2018	[-]
Lamoprazole	Medication	31 Mar 2011	[-]

CARE PLAN AT THE HEART OF C3-CLOUD



C3-CLOUD Home My Patients Schedule Messages 43 GB Logout

Penicillins with extended spectrum Rush 19 Mar 1994

George Best

Patient
Age: 84 (22 Jun 1934)
Gender: male
E-mail: george.Best@emailprovider.com
Phone: (178) 911 1111
Address: 1 The Street A Town GB AA11 2AA (home)

Encounters

Health Prof.	Location	Date
Dr. Peter Hutchinson +1	Rother House Medical Centre	20 Feb 2018
Pamela Cousins +1	Rother House Medical Centre	10 Feb 2018
Optomotrist	Boots the Chemist	10 Aug 2017
Mr. G. Mission	Warwick Hospital	06 Jun 2017
Mrs. Carbs	Rother House Medical Centre	23 Feb 2016
Mr. Foot	Community Clinic	09 Mar 2015

Care Barriers

Barrier	Value	Date
Tobacco smoking status	Ex-smoker	
Forgetting about medication	Uses walking stick on good day & walking frame on bad day. Must be accompanied by daughter to appointments	
Ignoring diabetic diet - likes chocolate		
Alcohol drink/w	2 drink/w	

Observations

Test	Value	Interpret	Date
Body height	175 cm		20 Feb 2018
Heart rate	80 /min		20 Feb 2018
Body mass index	25 kg/m2		20 Feb 2018
Body weight	90 kg		20 Feb 2018
Blood pressure panel with all children optional			20 Feb 2018
▶ Systolic blood pressure	170 mmHg		
▶ Diastolic blood pressure	90 mmHg		

Blood pressure panel with all children optional

Chart History

Date	Systolic blood pressure (mmHg)	Diastolic blood pressure (mmHg)
2018-01-11	180	90
2018-01-16	175	90
2018-01-23	165	85
2018-01-30	170	85
2018-02-06	165	85
2018-02-13	160	85
2018-02-20	170	90

C3-CLOUD Home My Patients Schedule Messages GB Peter Hutchinson

George Best

Patient
Age: 84 (22 Jun 1934)
Gender: male
E-mail: george.Best@emailprovider.com
Phone: (178) 911 1111
Address: 1 The Street A Town GB AA11 2AA (home)

Medical Summary of George Best

Last Data Retrieval from the Local EHR System: 02 Aug 2018 12:35

Please review the medical summary and click Continue to proceed. [Continue](#)

Conditions

Diagnosis	Date	Status
Depression	06 Jan 2019	Active
Mild cognitive impairment	01 Aug 2015	Active
Chronic kidney disease, stage 3	01 Jan 2015	Active
Prostate Cancer	02 Oct 2010	Active
Type 2 diabetes mellitus	02 Apr 2010	Active
Glaucoma	04 May 1998	Active
Hypertension	02 Mar 1993	Active
Hypothyroidism	10 Mar 1987	Active
Osteoarthritis of hand	13 Jul 2014	Inactive
Cerebral infarction	01 Dec 2012	Inactive

Medications

Product	Dose	Frequency	Commenced
Gliclazide	80 milligram	1 times per 1 day	01 May 2015
acetylsalicylic acid	75 mg	1 times per 1 day	10 Nov 2012
Metformin	500 milligram	2 times per 1 day	01 Oct 2010
Finasteride	5 milligram	1 times per 1 day	04 Aug 2010
tamsulosin	0.4 mg	1 times per 1 day	03 Feb 2008
latanoprost	55 ug	1 times per 1 day	16 Feb 2004
Timolol	0.25 %	1 times per 2 day	15 Aug 1998
Atorvastatin	40 milligram	1 times per 1 day	02 Apr 1998
Atenolol	50 milligram	1 times per 1 day	03 Aug 1994
Bendroflumethiazide	2.5 milligram	1 times per 1 day	01 Sep 1993

Allergies

Allergy	Reaction	Onset
Penicillins with extended spectrum	Rush	19 Mar 1994

Encounters

Health Prof.	Location	Date

Care Barriers

Barrier	Value	Date

Specific Challenges

- Clinical guidelines are single-disease centred; falling short for multi-morbidity
- Polypharmacy in elderly leads to more comorbidities and medications

C3-Cloud Objectives

- Enable personalised care plan development by reconciling clinical guidelines
- Provide several clinical decision support services to support personalized care plan development and management

C3-Cloud Results

- CRG led identification and reconciliation of clinical guidelines
- 43 flowcharts implemented as 41 CDS services (283 rules and 52 reconciliation rules)
- Drug-drug Interaction Service developed based on NICE BNF database

Clinical Decision Support

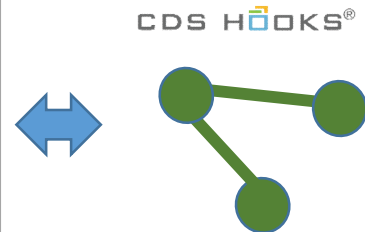
Clinical Decision Support Services

- The GDL2 CDS services are available on GitHub: <https://github.com/C3-Cloud-eu/gdl2-cds-services>
- Used by the C3DP to support healthcare professionals to develop and manage care plans

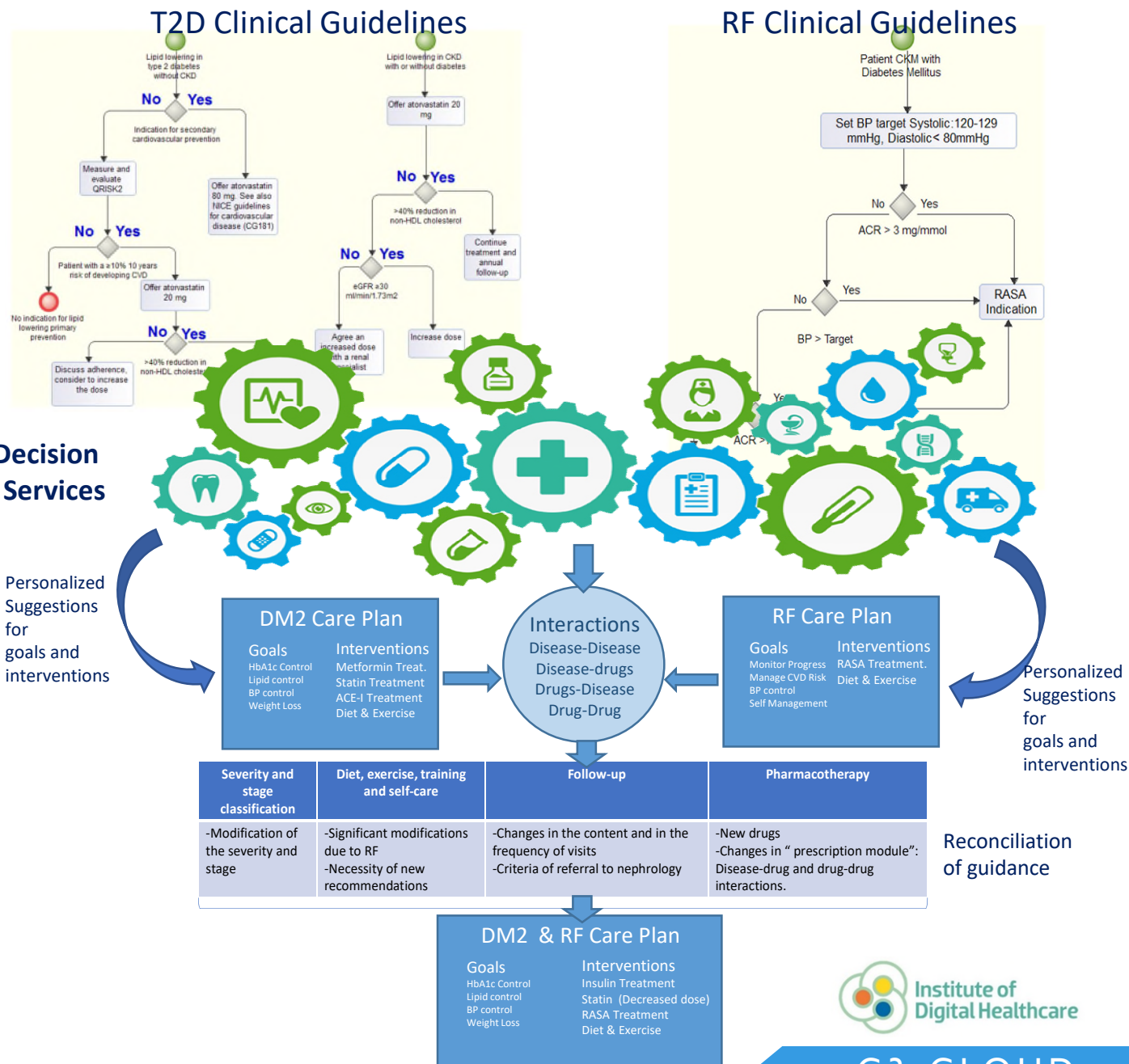
The screenshot shows a patient profile for Sven Karlsson, 73 years old. It includes a list of health concerns addressed (e.g., Essential (primary) hypertension, Non-insulin-dependent diabetes mellitus) and a list of goals (e.g., Keep HbA1c under 48 mmol/mol, Keep blood pressure under control). The interface also displays care barriers/patient status and a list of activities (e.g., Metformin twice a day, Measure blood pressure weekly).

C3DP

Clinical Decision Support Services

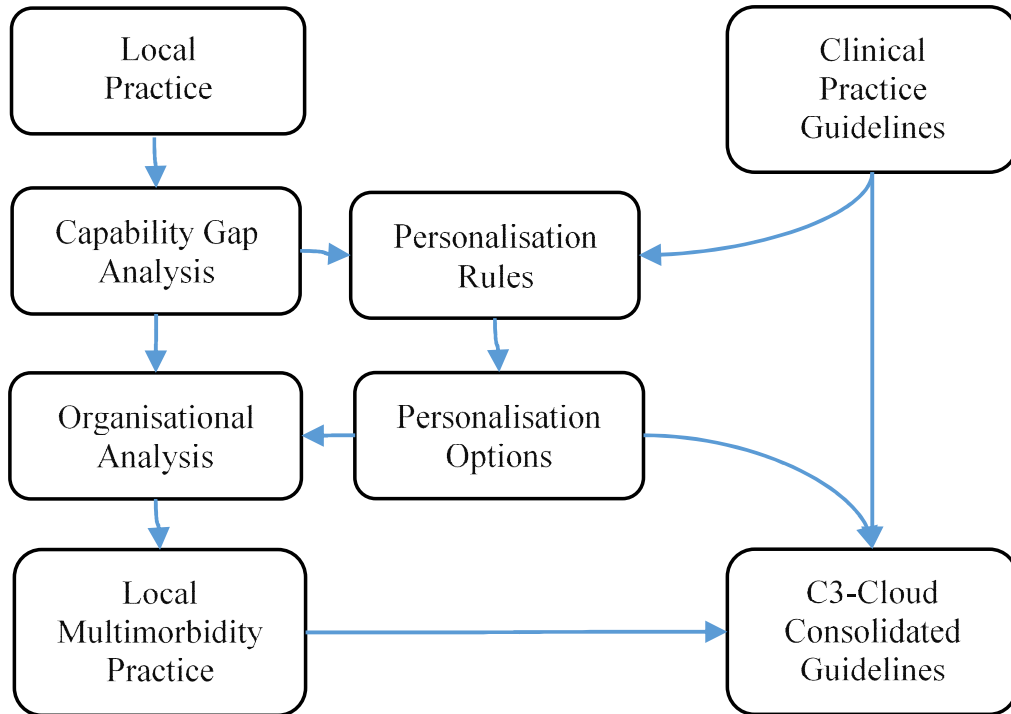


Personalized Suggestions for goals and interventions



Reconciliation of guidance





- Identification of best practice guidelines
- Identification of local practice
- Organisational transformation analysis
- Development of personalisation rules
- Identification of conflicts
- Reconciliation of conflicts
- Validation of consolidated guidelines

Specific Challenges

- **Patients** and their **informal care givers** often do not have a **voice** in their own care

C3-Cloud Objectives

- Ensure active participation of patients and their informal care givers

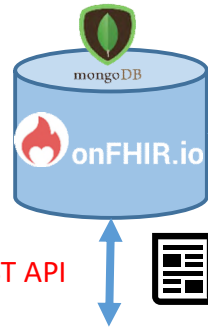
C3-Cloud Results

- C3-Cloud integrated care approach and supporting bundle of ICT tools, including the Patient Empowerment Platform
- Improved cooperation among formal and informal caregivers
- Increased participation of patients in care management

Patient Empowerment

Care Team – Patient Collaboration

- Care plan access
- Reminders to increase adherence
- Actively collect data related to the care plan activities
- Safe messaging
- Access to relevant self-management material



HL7® FHIR® REST API



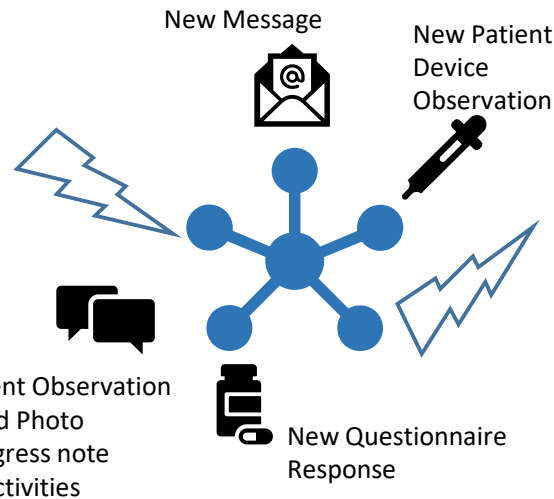
New/Updated Care Plan
New Updated Care Team

HL7® FHIR® REST API

MEDIXINE

HL7® FHIR® Care Plan Model

Personalised Care Plan Management
C3DP (for professionals)



Event Notification Integration

PEP (for patients / care givers)



PATIENT EMPOWERMENT



C3CLOUD SK Sven Karlsson(a1)

Home Careplan Tracking Questionnaires Guidance

Activities 7
Your activities

Scheduled activities

Activity	When	Actions
Enalapril once a day	Every day 1 time at breakfast	Add note
Daily meal photo	Every day 3 times at a meal from 2017-12-02 to 2017-12-09	Add note
Fill in lifestyle questionnaire	Once between 2017-11-22 to 2017-12-09	Add note
Follow the diet	Every day 5 times at 08:00, 10:30, 13:00, 16:00, 19:00 from 1999-08-13 to 2016-09-06	Add note
Measure blood pressure weekly	every week 1 time during the morning from 2009-07-21	Add note
Metformin twice a day	Every day 2 times (at breakfast and at dinner)	Add note
Atorvastatin 20mg	Every day 1 time (at breakfast)	Add note

Guidance 3
Guidance material assigned to you.

- [Type 2 diabetes Diet for Healthy Eating](#)
<https://patient.info/health/type-2-diabetes>
- [Type 2 diabetes](#)
<https://patient.info/health/type-2-diabetes>
- [High blood pressure\(hypertension\)](#)
<https://patient.info/health/high-blood-pressure-hypertension>



Specific Challenges

- Managing multi-morbidity without informed involvement of all stakeholders, resulting in specialty silos and fragmented care
- Existing organisational models and care pathways are inadequate for integrated care delivery

C3-Cloud Objectives

- Enable MDT members to collaboratively manage integrated care plans, and support them to provide the best possible care
- Seamlessly integrate with the existing health and social care information systems
- Identify best practices in caring for multi-morbid patients across sites

C3-Cloud Results

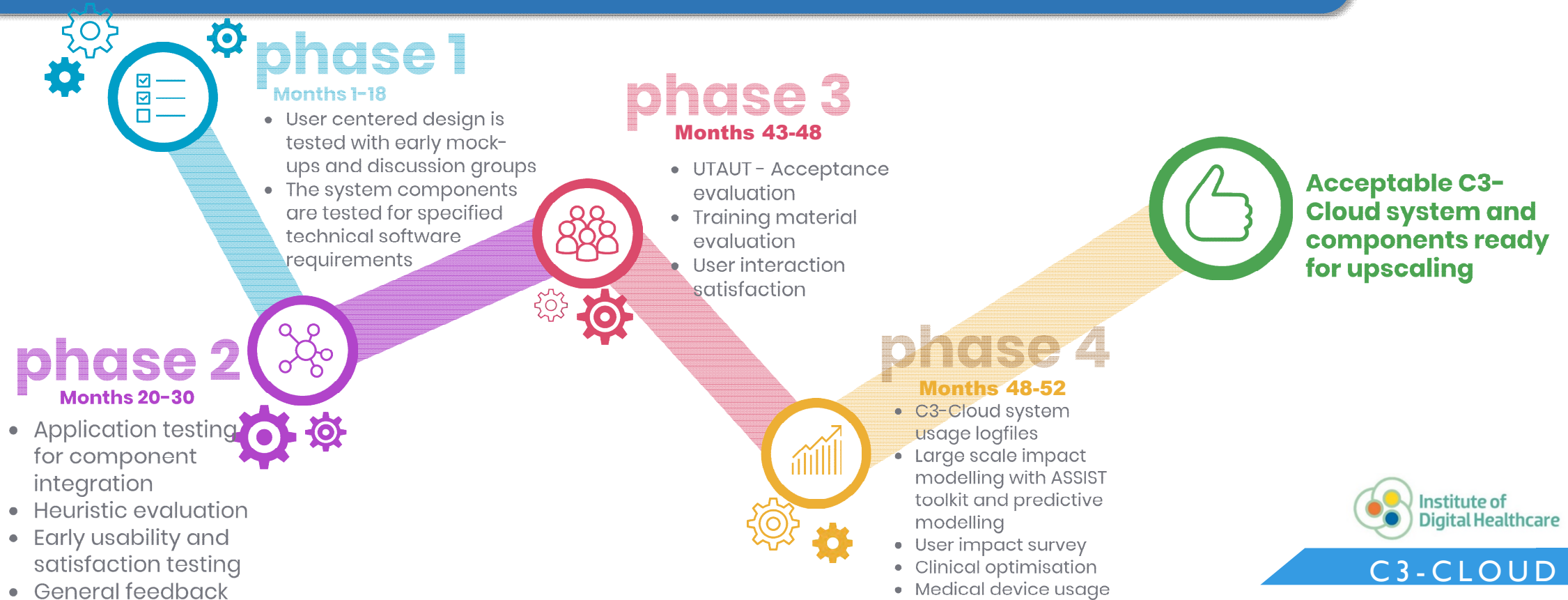
- C3-Cloud approach validated in **3 European regions** with diverse health systems and underlying infrastructures
- An innovative **large-scale impact modelling tool** for industrial exploitation and large-scale roll out
- Addition to **evidence** for optimised multimorbidity care pathways and organisational models

Validation of C3-Cloud approach

TECHNOLOGY TRIAL



Is the use of a personalised ICT tool that facilitates coordinated care planning, treatment optimisation and patient self-management acceptable to patients with multiple long-term conditions and their team of health professionals?



STUDY RESULTS



**Cautious acceptance:
UTAUT patients: 4.76
UTAUT MDT: 4.00**



**Satisfaction can
be increased**



Consider benefit shifts



**Healthcare provider
organizations save time**



Payers save money



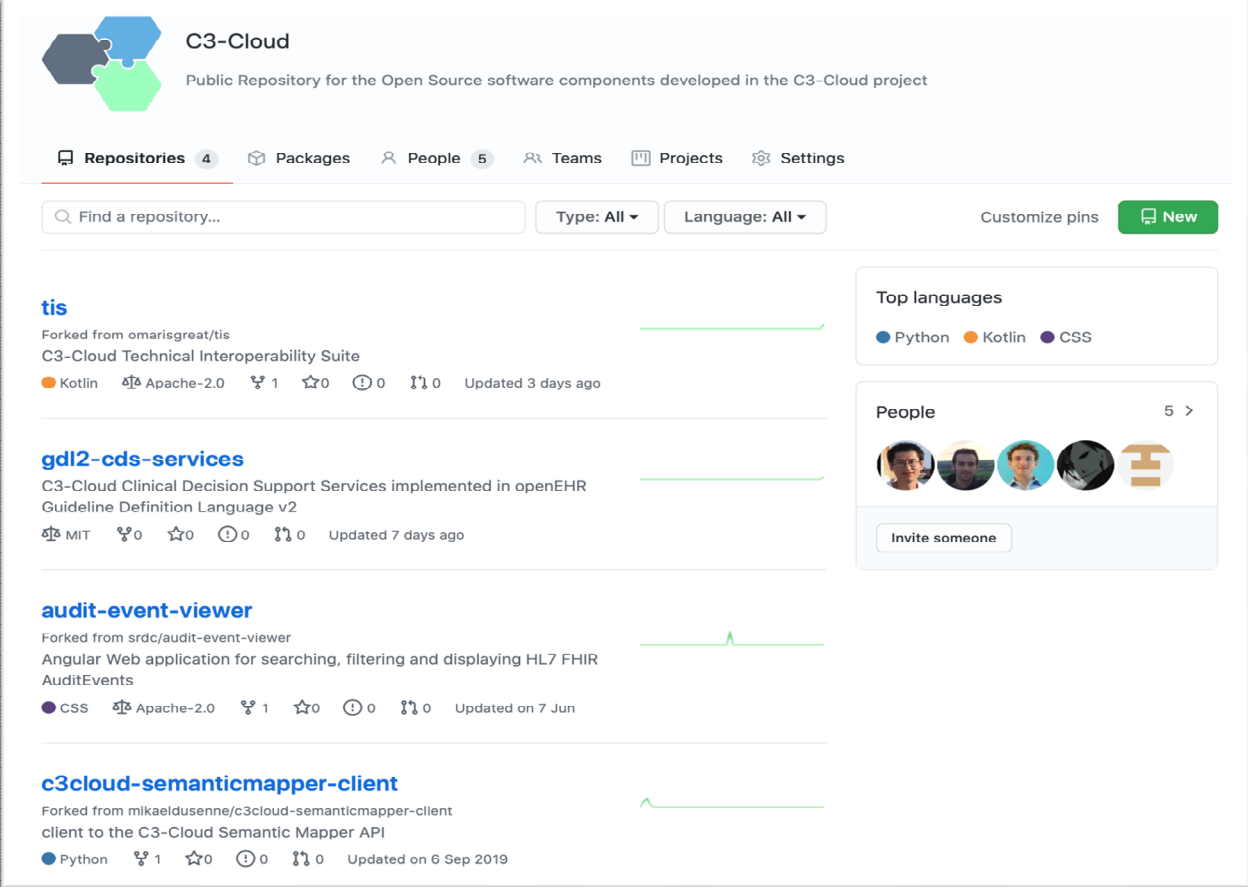
**Operational benefits
are key**



Upscaling suggested

OPEN SOURCE REPOSITORY

- The Audit Event Viewer developed by SRDC.
- The Semantic Mapper client developed by INSERM,
- GDL2 CDS services developed by CAMBIO,
- A Technology Interoperability Suite (TIS) developed by WARWICK,



The screenshot displays the C3-Cloud Open Source Repository interface. At the top, the repository name "C3-Cloud" is shown with a logo of three interlocking puzzle pieces in blue, green, and orange. Below the name, it states "Public Repository for the Open Source software components developed in the C3-Cloud project". Navigation tabs include "Repositories" (4), "Packages", "People" (5), "Teams", "Projects", and "Settings". A search bar is present with the placeholder "Find a repository...". Filter buttons for "Type: All" and "Language: All" are visible, along with a "Customize pins" link and a "New" button. The main content area lists four repositories:

- tis**: Forked from omarisgreat/tis, C3-Cloud Technical Interoperability Suite. Languages: Kotlin, Apache-2.0. 1 fork, 0 stars, 0 issues, 0 pull requests. Updated 3 days ago.
- gdl2-cds-services**: C3-Cloud Clinical Decision Support Services implemented in openEHR Guideline Definition Language v2. License: MIT. 0 forks, 0 stars, 0 issues, 0 pull requests. Updated 7 days ago.
- audit-event-viewer**: Forked from srdc/audit-event-viewer, Angular Web application for searching, filtering and displaying HL7 FHIR AuditEvents. Language: CSS, License: Apache-2.0. 1 fork, 0 stars, 0 issues, 0 pull requests. Updated on 7 Jun.
- c3cloud-semanticmapper-client**: Forked from mikaeldusenne/c3cloud-semanticmapper-client, client to the C3-Cloud Semantic Mapper API. Language: Python. 1 fork, 0 stars, 0 issues, 0 pull requests. Updated on 6 Sep 2019.

On the right side, there are two sidebars: "Top languages" showing Python, Kotlin, and CSS; and "People" showing 5 contributors with a profile picture and an "Invite someone" button.

FOREGROUND IP ASSETS AND INNOVATION RADAR



Application site integration Toolkit: provides means for organizations to assess their readiness to deploy (or connect to) a C3-Cloud healthcare service

Market maturity: Market Ready
Project: C3-Cloud
Innovation Topic: Health & Care

SRDC YAZILIM ARASTIRMA VE GELISTIRME VE
DANISMANLIK TICARET ANONIM SIRKETI - TURKEY
THE UNIVERSITY OF WARWICK ♀ - UNITED KINGDOM
INSTITUT NATIONAL DE LA SANTE ET DE LA RECHERCHE
MEDICALE - FRANCE

3 GOOD HEALTH
AND WELL-BEING

C3 Cloud Architecture: providing healthcare professionals with guideline-based recommendations for patients based on automated interpretation of available data

Market maturity: Market Ready
Project: C3-Cloud
Innovation Topic: Health & Care

SRDC YAZILIM ARASTIRMA VE GELISTIRME VE
DANISMANLIK TICARET ANONIM SIRKETI - TURKEY
THE UNIVERSITY OF WARWICK ♀ - UNITED KINGDOM
INSTITUT NATIONAL DE LA SANTE ET DE LA RECHERCHE
MEDICALE - FRANCE

3 GOOD HEALTH
AND WELL-BEING

Clinical Guidelines: Interpretation, Specification, Implementation, and Execution

Market maturity: Market Ready
Project: C3-Cloud
Innovation Topic: Health & Care

SRDC YAZILIM ARASTIRMA VE GELISTIRME VE
DANISMANLIK TICARET ANONIM SIRKETI - TURKEY
THE UNIVERSITY OF WARWICK ♀ - UNITED KINGDOM
CAMBIO HEALTHCARE SYSTEMS AB - SWEDEN

3 GOOD HEALTH
AND WELL-BEING

Functional implementation of C3-Cloud components

Market maturity: Market Ready
Project: C3-Cloud
Innovation Topic: Health & Care

THE UNIVERSITY OF WARWICK ♀ - UNITED KINGDOM
INSTITUT NATIONAL DE LA SANTE ET DE LA RECHERCHE
MEDICALE - FRANCE
MEDIXINE OY - FINLAND

3 GOOD HEALTH
AND WELL-BEING

KEY POINTS

- Integrated Care Delivery End-to-end Solution
- Tackling Health Challenges on Chronic Diseases: Multimorbidity and Polypharmacy
- New patient pathways & corresponding care plans that can perform multi-morbid chronic disease management
- Care Team – Patient/Informal Career Co-operation
- Development of guidelines for smooth management of changes in models of care delivery
- Validation of Solution
- **Digitally-enabled integrated care the way forward:** The benefits to individuals and society are multiple. People's health journeys are better understood and appropriate **lifestyle choices can be better tailored and promoted to the individual.**
- In the case of chronic conditions, **disease management** can be more **effectively supported** and **avoidable deaths can be prevented.**



THANK YOU



Any questions?

t.arvanitis@warwick.ac.uk



Osakidetza

