

# **KOS-based tools for archaeological dataset interoperability: NKOS Workshop, ECDL 2010**

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Arts & Humanities  
Research Council

# STAR Project

## Semantic Technologies for Archaeological Resources

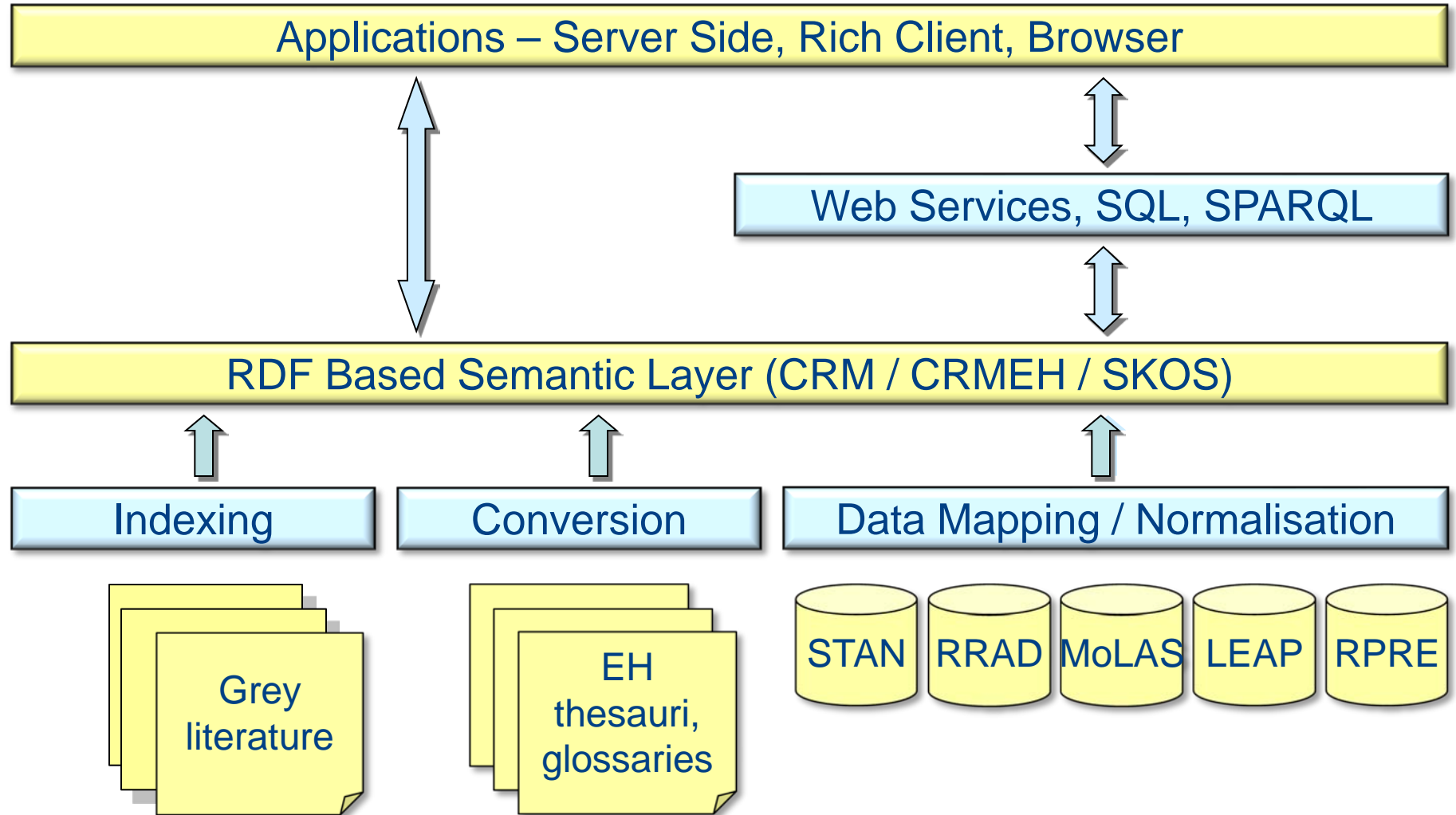
- AHRC funded project
- In collaboration with English Heritage
- <http://hypermedia.research.glam.ac.uk/kos/star/>



# STAR Aims and Background

- *Investigate the potential of semantic terminology tools for widening access to digital archaeology resources, including disparate data sets and associated grey literature*
- *Open up the grey literature to scholarly research by investigating the combination of linguistic and KOS-based methods in the digital archaeology domain.*
- *Develop new methods for enhancing linkages between digital archive database resources and to associated grey literature, exploiting the potential of a high level, core ontology.*
- Current situation one of fragmented datasets and applications, with different terminology systems
- Need for integrative metadata framework  
EH have designed an upper ontology based on CRM standard

# STAR Project - General Architecture



# CRM Event Based model - Property chains

- CRM event model – events not explicit in datasets OR mappings
  - Additional work required to satisfy logical mappings
- E.g. **Sample** *taken from* **Context**:

**crmeh:EHE0018.Sample** [*crm:E18.PhysicalStuff*]

→ *crm:P113B.was\_removed\_by*

→ crmeh:EHE2006.ContextSamplingEvent

[*crm:E80.PartRemoval*]

→ *crm:P112F.diminished*

→ crmeh:EHE0008.ContextStuff [*crm:E18.PhysicalStuff*]

→ crmeh:EHP3.occupied

→ **crmeh:EHE0007.Context** [*crm:E53.Place*]

# RDF Data Extraction Tool

SQLBuilder v1.0

File

Database: RRAD

Subject: Type: Prefix: Column: Predicate: Object: Literal value:

FROM clause: WHERE clause:

Generated SQL:

```
SELECT DISTINCT
" AS [SUBJECTTYPE],
'http://tempuri/star/base#.rad.' & AS [SUBJECT],
" AS [PREDICATE],
" AS [OBJECTTYPE],
'http://tempuri/star/base#.rad.' & AS [OBJECT],
" AS [LITERAL]
FROM
WHERE 1 = 1
```

Resultant Data:

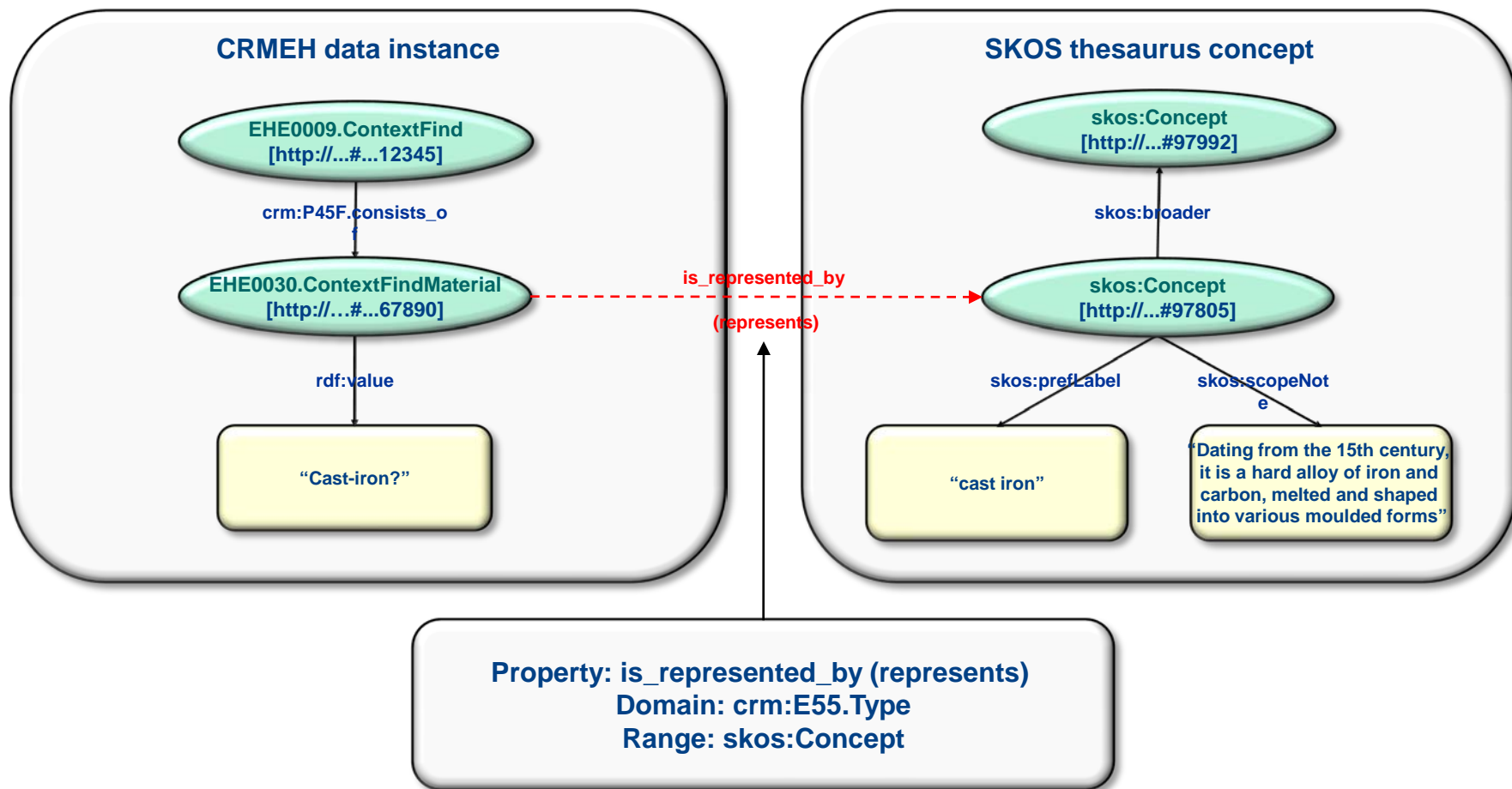
Test SQL

Write RDF...

# Resultant extracted data (RDF/XML)

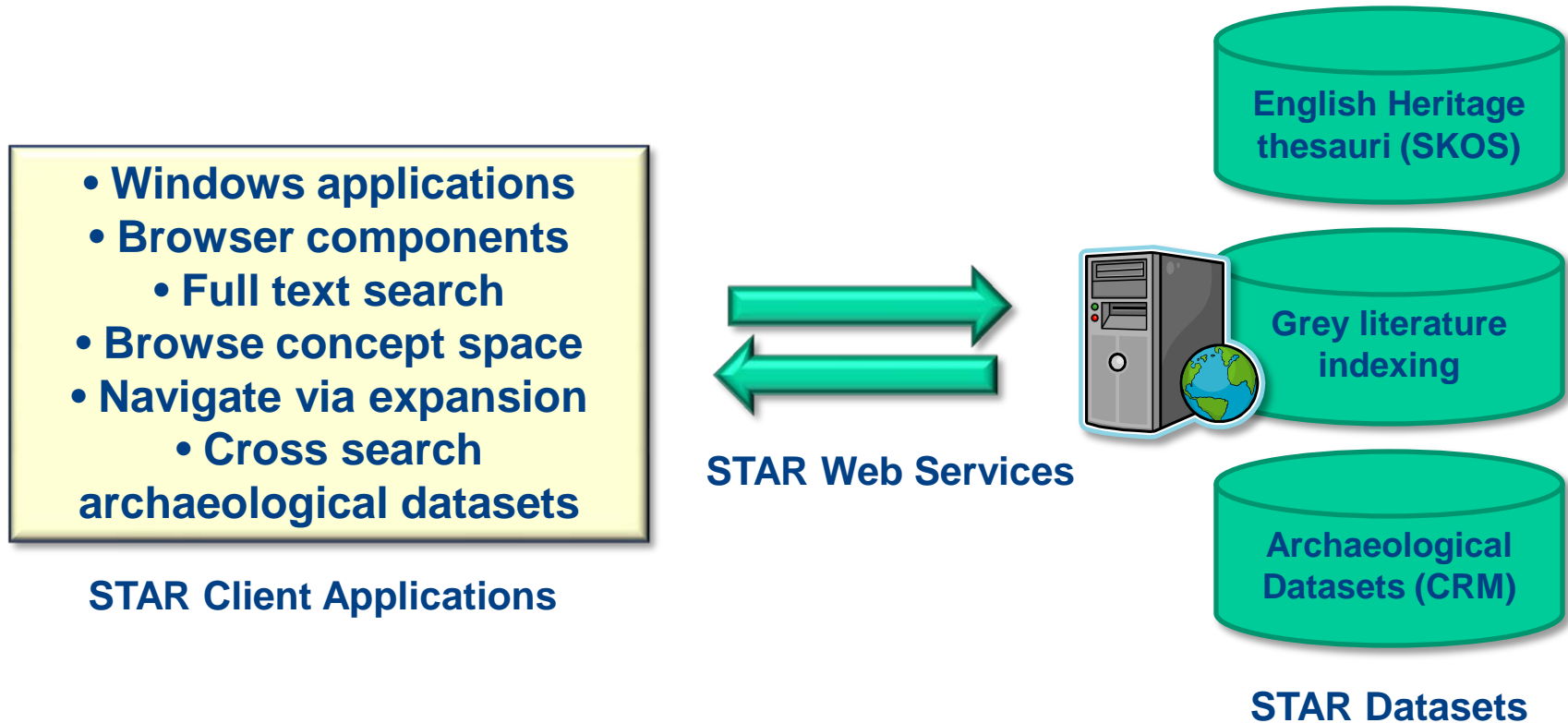
```
<?xml version="1.0"?>
<rdf:RDF xmlns:crneh="http://tempuri/star/crneh#" xmlns:crm="http://cidoc.ics.forth.gr/rdfs/cidoc_v4.2.rdfs#" xmlns:rdf="http://www.w3.org/1999/02/22-
rdf-syntax-ns#" xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#" xml:base="http://tempuri/star/base#">
  <crneh:EHE0007.Context rdf:about="http://tempuri/star/base#ehe0007.rrad.context.contextno.1">
    <crm:P3F.has_note>
      <crneh:EHE0046.ContextNote rdf:about="http://tempuri/star/base#ehe0046.rrad.context.description.1">
        <rdf:value>Upper ploughsoil over whole site no Sub-division for the convenience of finds processing '1' contains finds contexts '3759',
'3760' and '3763'</rdf:value>
      </crneh:EHE0046.ContextNote>
    </crm:P3F.has_note>
  </crneh:EHE0007.Context>
  <crneh:EHE0007.Context rdf:about="http://tempuri/star/base#ehe0007.rrad.context.contextno.2">
    <crm:P3F.has_note>
      <crneh:EHE0046.ContextNote rdf:about="http://tempuri/star/base#ehe0046.rrad.context.description.2">
        <rdf:value>Sub-division of '60' in villa area.</rdf:value>
      </crneh:EHE0046.ContextNote>
    </crm:P3F.has_note>
  </crneh:EHE0007.Context>
  <crneh:EHE0007.Context rdf:about="http://tempuri/star/base#ehe0007.rrad.context.contextno.3">
    <crm:P3F.has_note>
      <crneh:EHE0046.ContextNote rdf:about="http://tempuri/star/base#ehe0046.rrad.context.description.3">
        <rdf:value>Destruction layer of building material over main villa structure. Consists of much wallstone and roof slate (stone). Also mortar;
some tile; op sig, wall plaster and tesserae. Lying immediately beneath the lower ploughsoil (2) it mounds up over the middle of the building, thinning out
towards the edges. It is cut by a series of deep plough marks, remnant of medieval ridge and furrow which does not show at ground level. To the east of
corridor 24, the destruction material contains more mortar than on the west - also some box flue tile</rdf:value>
      </crneh:EHE0046.ContextNote>
    </crm:P3F.has_note>
  </crneh:EHE0007.Context>
  <crneh:EHE0007.Context rdf:about="http://tempuri/star/base#ehe0007.rrad.context.contextno.4">
    <crm:P3F.has_note>
      <crneh:EHE0046.ContextNote rdf:about="http://tempuri/star/base#ehe0046.rrad.context.description.4">
        <rdf:value>A shallow linear depression orientated on an east-west axis running across the width of excavation. Original recorded
coordinates: 0980/0980</rdf:value>
      </crneh:EHE0046.ContextNote>
    </crm:P3F.has_note>
  </crneh:EHE0007.Context>
```

# STAR implementation - linking CRM instances to SKOS concepts

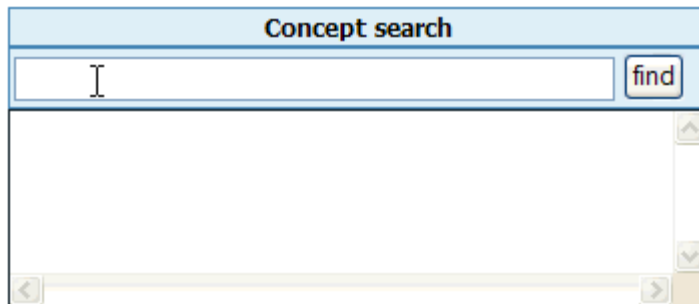




# STAR – Web Services and Client Applications

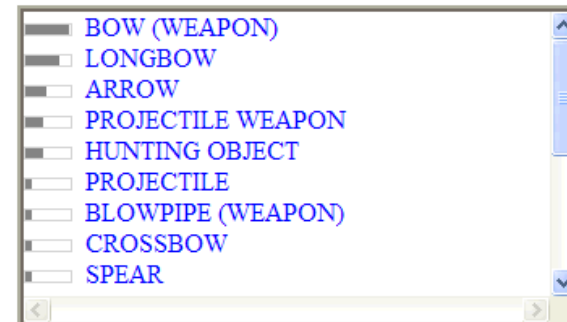


# STAR – Web Client Components



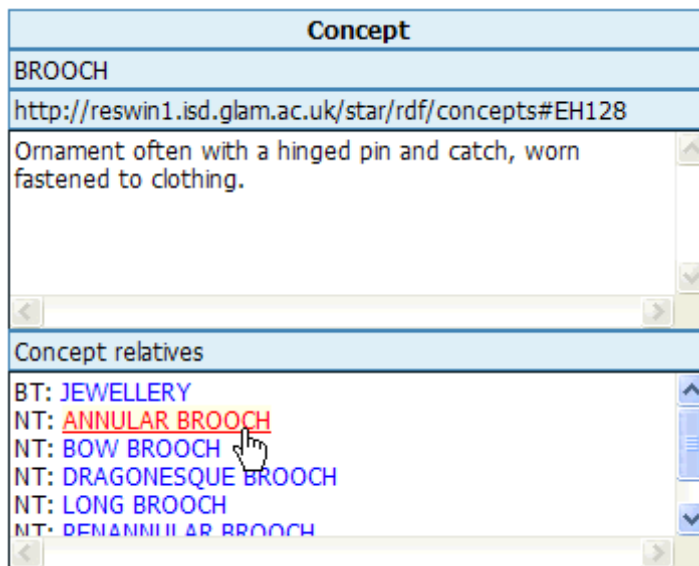
A web interface for concept searching. It features a title bar 'Concept search', a text input field with a cursor, and a 'find' button. Below the input field is a large, empty rectangular area for search results, with a vertical scrollbar on the right and a horizontal scrollbar at the bottom.

Search across multiple thesauri



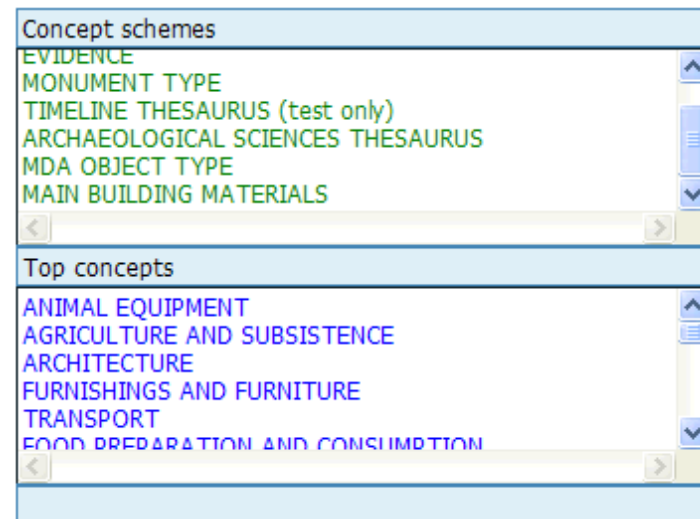
A list of concepts for semantic expansion. The list includes: BOW (WEAPON), LONGBOW, ARROW, PROJECTILE WEAPON, HUNTING OBJECT, PROJECTILE, BLOWPIPE (WEAPON), CROSSBOW, and SPEAR. Each item is preceded by a small square icon. The list is contained within a window with a title bar and scrollbars.

Navigate via semantic expansion



A detailed view of a concept. The title bar is 'Concept'. The main content area shows the word 'BROOCH' in a blue header, followed by a URL 'http://reswin1.isd.glam.ac.uk/star/rdf/concepts#EH128' and a description: 'Ornament often with a hinged pin and catch, worn fastened to clothing.' Below this is a section titled 'Concept relatives' containing a list of related terms: BT: JEWELLERY, NT: ANNULAR BROOCH (highlighted with a red cursor), NT: BOW BROOCH, NT: DRAGONESQUE BROOCH, NT: LONG BROOCH, and NT: PENANNULAR BROOCH. The list has a vertical scrollbar on the right.

Display concept details



A window for browsing available thesauri. It has a title bar 'Concept schemes' and a list of thesauri: EVIDENCE, MONUMENT TYPE, TIMELINE THESAURUS (test only), ARCHAEOLOGICAL SCIENCES THESAURUS, MDA OBJECT TYPE, and MAIN BUILDING MATERIALS. Below this is a section titled 'Top concepts' with a list of concepts: ANIMAL EQUIPMENT, AGRICULTURE AND SUBSISTENCE, ARCHITECTURE, FURNISHINGS AND FURNITURE, TRANSPORT, and FOOD PREPARATION AND CONSUMPTION. The lists have vertical scrollbars on the right.

Browse available thesauri

## Preliminary prototype application

- Incorporated SKOS based thesaurus query expansion in search
- Colour coding of results by source dataset
- Browse results and drill down
- Open links to external data if available

# STAR web browser based search interface

The screenshot displays the STAR web browser based search interface, which is organized into several panels:

- Search Parameters Panel (Left):** Contains tabs for Groups, Contexts, Finds, and Samples. Under the Contexts tab, search criteria are defined: Site (checked), Context ID (checked), Context Type (checked, set to "post-hole"), Context Notes (checked), Within Group (checked), Within Context (checked), Contains Context (checked), Contains Context Find (checked), Contains Context Sample (checked), Sample ID (checked), Sample Type (checked), and Sample Notes (checked). A search term "grain" is entered in the search box. Below the search box is a "Run Query" button.
- Search Results Panel (Bottom Left):** Displays a list of search results, including 665, 903, 970, 67349, 65968, and 68122. A label "Search results" is overlaid on this panel.
- Group Details Panel (Top Middle):** Shows a hierarchical tree structure of groups. The root node is 151569, which branches into 121896. 121896 further branches into 68122 and 68123. A label "Group details" is overlaid on this panel.
- Context Details Panel (Top Right):** Shows a hierarchical tree structure of contexts. The root node is 121896, which branches into 68122. 68122 further branches into 80128 and 91340. A label "Context details" is overlaid on this panel.
- Context Sample Details Panel (Bottom Middle):** Shows a hierarchical tree structure of context samples. The root node is 80122, which branches into 80128. A label "Sample details" is overlaid on this panel.
- Context Find Details Panel (Bottom Right):** Shows a hierarchical tree structure of context finds. The root node is 80128, which branches into 91340. A label "Find details" is overlaid on this panel.

The interface also includes a "Run Query" button and a "6 results" indicator at the bottom left.

# Initial search

The screenshot displays a web-based archaeological database search interface. The interface is divided into several sections:

- Search Parameters (Left Panel):** A list of search criteria with checkboxes. A red box highlights the following parameters: Site, Context ID, Context Type, Context Notes, Within Group, Within Context, Contains Context, Contains Context Type, Contains Context Sample, Sample ID, Sample Type, and Sample Notes. The search term "grain" is entered in the search box.
- Search Results (Bottom Left):** A list of 6 results, each with a unique ID: 665, 903, 970, 67349, 65966, and 68122.
- Search Criteria (Middle Panel):** A list of search criteria with checkboxes: Site, Group ID, Group Type, Group Notes, Within Group, Contains Group, and Contains Context.
- Stratigraphic Diagram (Right Panel):** A diagram showing the relationship between different archaeological contexts. It includes a tree structure with nodes labeled with IDs: 121896, 68122, 80128, 86378, and 91340. The diagram is titled "Stratigraphy" and "Details".
- Search Interface (Top):** A header bar with tabs for Groups, Contexts, Finds, and Samples. A "Run Query" button is located below the search criteria list.

The search results are displayed in a table with the following data:

ID
665
903
970
67349
65966
68122

The stratigraphic diagram shows a hierarchy of contexts. The root node is 121896, which is connected to 68122. 68122 is connected to 80128. 80128 is connected to 86378. 86378 is connected to 91340. The diagram is titled "Stratigraphy" and "Details".

# Context details

The screenshot displays a software interface for managing archaeological data. The main panel shows a hierarchy diagram for context 3214, which is an "Open industrial hearth". The diagram includes context 50018, context 3214, and context BF2714. The details panel provides information about the site (#ehe0001.leap), context ID (3214), context type (Open industrial hearth), and a URL. The sidebar lists various filters and a list of results.

**Context Details Hierarchy**

```
graph TD; 50018 --> 3214; 3214 --> BF2714; BF2714 --> BF2714; BF2714 --> BF2714
```

**Context Details**

**Hierarchy** **Stratigraphy**

Site: #ehe0001.leap

Context ID: 3214

Context Type: Open industrial hearth

<http://tempuri/star/base#ehe0007.leap.contexts.context.3214>

**Sample ID**

80128

**Sample Type**

Dry soil

**Sample Notes**

**Find ID**

91340

**Find Type**

Nail

**Find Dating**

6 results

# Context find details

The screenshot displays a software interface for managing archaeological data. The main window is titled 'Context Find Details' and shows a hierarchical diagram of a find. The diagram consists of a yellow box labeled '3994' connected by a line to a blue box labeled 'SF2745'. The 'SF2745' box has a dashed border. Below the diagram, a table lists the details of the find:

Field	Value
Site	#ehe0001.leap
Find ID	SF2745
Find Type	Jewellery Ring Fragment
Find Dating	
<a href="http://tempuri/star/base#ehe0009.leap.finds.id.sf2745">http://tempuri/star/base#ehe0009.leap.finds.id.sf2745</a>	

On the left side of the interface, there is a sidebar with a tree view showing the following structure:

- Groups
  - Contexts
    - Finds
      - Samples

Below the tree view, there is a 'Run Query' button and a list of results:

Result
665
903
970
67349
65966
68122

At the bottom of the interface, there is a status bar showing '6 results' and a list of URLs for each result.

On the right side of the interface, there is a 'Context Details' panel with tabs for 'Hierarchy' and 'Stratigraphy'. The 'Hierarchy' tab is selected, showing a diagram of the context hierarchy. The diagram consists of a yellow box labeled '121896' connected by a line to a blue box labeled '68122'. The '68122' box has a dashed border. Below the diagram, a table lists the details of the context:

Field	Value
Context ID	68122
Context Type	
Context Notes	
Within Group	
Within Context	
Contains Context	
Contains Context Find	
Contains Context Sample	
Sample ID	
Sample Type	
Sample Notes	
Stratigraphically Above Context	

Below the table, there is a 'Find details' panel with a diagram showing a yellow box labeled '86378' connected by a line to a blue box labeled '91340'. The '91340' box has a dashed border. Below the diagram, a table lists the details of the find:

Field	Value
Find ID	91340
Find Type	Nail
Find Dating	

# Context sample details

Groups

Contexts

Finds

Samples

Site

Context ID

Context Type

post-hole

Context Notes

Within Group

Within Context

Contains Context

Contains Context Find

Contains Context Sample

Sample ID

Sample Type

Sample Notes

grain

Stratigraphically Above Context

Run Query

665

903

970

67349

65966

68122

Group Details

Context Details

Hierarchy

Stratigraphy

Context Sample Details

503

118

Site

#ehe0001.molas.rop95

Sample ID

118

Sample Type

Sample Notes

http://tempuri/star/base#ehe0018.molas.env\_process\_gen.sample.rop

Sample ID

80128

Sample Type

Dry soil

Sample Notes

Find ID

91340

Find Type

Nail

Find Dating

121896

68122

80128

86378

91340

6 results

http://tempuri/star/base#ehe0018-rad.sample.samples.90128

http://tempuri/star/base#ehe0000-rad.object.objects.91340



# Group details

The screenshot displays a software interface for managing archaeological data. The main window, titled "Group Details", shows a hierarchical diagram of a site. The diagram consists of a green box labeled "154123" at the top, which is connected to a dashed green box labeled "128334". Below "128334" are two boxes: a green one on the left and an orange one on the right labeled "45810 45857". A mouse cursor is pointing at the orange box. The interface also includes a sidebar with filters, a details panel on the right, and a bottom section with a list of results.

**Group Details**

Site

Group ID  
128334

Location  
1070E 1240N

Group Type

Group Notes

<http://tempuri/star/base#ehe0005.rrad.subgroup.subgroupno.128334>

**Context Details**

Hierarchy

121896

68122

80128

86378

91340

**Find Details**

Find Type

Nail

Find Dating

6 results

# Grey Literature Information Extraction

## (Andreas Vlachidis)

An archaeological evaluation was carried out by ECC FAU on behalf of Essex Police on the site of a proposed new police station at Smiths Farm, on the southeastern outskirts of Great Dunmow, Essex. The site was formerly rough pasture. The Chelmsford Road, which is thought to be the line of a Roman road, runs immediately to the east of the site. Five 30m x 2m trenches were excavated within the footprint of the proposed building and the area of associated carpark. Only one archaeological feature was revealed, a ditch containing prehistoric pottery dating to the Late Bronze Age or Early Iron Age along with burnt flints and flint flakes. No other archaeological features were identified, although a number of prehistoric pottery sherds and flint flakes were discovered on the surface of the natural geology. Although the results of the evaluation do not suggest intensive landscape use during the Late Bronze/ Early Iron Ages it is clear from this and other nearby investigations that a focus for the low level activity seen may well lie in the general vicinity. The absence of Roman or medieval remains indicates that this site was well outside the settlements of these periods. The low quantity and quality of the remains encountered on the site suggests that there is only a minor archaeological implication for the location of the proposed police

- Looking to extract CRM-EH period, context, find, sample entities
- Aim to cross search within data

LATE BRONZE AGE OR EARLY IRON AGE	<table><tr><td>Term</td><td>skos</td></tr><tr><td>LATE BRONZE AGE</td><td>134734</td></tr><tr><td>EARLY IRON AGE</td><td>134735</td></tr></table>	Term	skos	LATE BRONZE AGE	134734	EARLY IRON AGE	134735	E49_Time_Appellation #text 5
Term	skos							
LATE BRONZE AGE	134734							
EARLY IRON AGE	134735							
ROMAN OR MEDIEVAL	<table><tr><td>Term</td><td>skos</td></tr><tr><td>ROMAN</td><td>134738</td></tr><tr><td>MEDIEVAL</td><td>134745</td></tr></table>	Term	skos	ROMAN	134738	MEDIEVAL	134745	<div><p><b>EARLY IRON AGE</b></p><p><b>Broad Term:</b> IRON AGE</p><p><b>Top Term:</b> CULTURAL PERIOD</p></div>
Term	skos							
ROMAN	134738							
MEDIEVAL	134745							
PREHISTORIC PERIOD	<table><tr><td>Term</td><td>skos</td></tr><tr><td>PREHISTORIC</td><td>134718</td></tr></table>	Term	skos	PREHISTORIC	134718	#text 2		
Term	skos							
PREHISTORIC	134718							

# Example STAR use of URIs (NLP)

```
<crmeh:EHE0007.Context rdf:about="http://tempuri/star/base#suffolkc1-3166.22923">
<dc:source rdf:resource="http://tempuri/star/base#suffolkc1-3166" />
<dc:source rdf:resource="http://tempuri/star/base#ehe0001.oasis" />
  <crm:P2F.has_type>
    <crm:E55.Type>
      <rdf:value>walls</rdf:value>
      <crmeh:EXP10F.is_represented_by
        rdf:resource="http://tempuri/star/concept#ehg003.93"/>
      <crmeh:EXP10F.is_represented_by
        rdf:resource="http://tempuri/star/concept#70426"/>
    </crm:E55.Type>
  </crm:P2F.has_type>
  <crm:P3F.has_note>
    <crm:E62.String>
      <rdf:value>...structure with a ...</rdf:value>
    </crm:E62.String>
  </crm:P3F.has_note>
</crmeh:EHE0007.Context>
```

# STELLAR

- [STELLAR](#) aims to generalise and extend the data extraction tools produced by STAR and enable third party data providers to use them.”
- The extracted data will be represented in standard formats that allow the datasets to be cross searched and linked by a variety of Semantic Web tools, following a linked data approach.

## **Objectives**

- Develop best practice guidelines for mapping and extraction of archaeological datasets into RDF/XML representation conforming to the CIDOC CRM-EH standard ontology
- Develop an enhanced tool for non-specialist users to map and extract archaeological datasets into RDF/XML representation conforming to CIDOC CRM-EH
- Develop best practice guidelines and tools for generating corresponding [Linked Data](#)
- Evaluate the mapping tool and the Linked Data provision
- Engage with the archaeological community to inform research and disseminate outcomes

# STELLAR - Data Processing Stages

- Parsing source data
  - Excel spreadsheets
  - Delimited data files (CSV)
- Cleansing / Manipulation
  - Trim space
  - Force uppercase / lowercase
  - replace text
  - add prefix / suffix
  - url encoding
  - Semantic enrichment
- Mapping
  - Columns to template placeholders
- Transformation
  - Apply templates to tabular data
- Validation
  - Validate output for coherence

# STELLAR – templates and placeholders

SITECODE	CONTEXT	ACC_NO	MATE	E_DATE	MAX_DIAM	COMMENTS	OBJECTID
BA84	597	2657	COPP	1302	20	SF NO 258; UNOFFICIAL STERLING	1649
BA84	569	2652	COPP	1285	23	SF NO 427; FRENCH	1650
BA84	1108	2656	COPP	1280	19	SF NO 418; BARBAROUS PRIVATE ISSUE	1651
BA84	2406	2663	COPP	1415	27	SF NO 884; TOURNAI STOCK JETTON	1652

```

$OBJECT_URI$ = "#e19." + ACC_NO
$OBJECT_IDENTIFIER$ = ACC_NO
$OBJECT_NOTES$ = COMMENTS
$MEASUREMENT_VALUE$ = MAX_DIAM
$PLACE_URI$ = "#e53." + SITECODE + "-" + CONTEXT

```

## Tabular data columns mapped to template placeholders

```

<?xml version="1.0"?>
<rdf:RDF
  xmlns:crm="http://cidoc.ics.forth.gr/rdfs/cidoc_v4.2.rdfs#"
  xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
  xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#">

  <crm:E19.PhysicalObject rdf:about="$OBJECT_URI$"
    <crm:P1F.is_identified_by>
      <crm:E41.Appellation>$OBJECT_IDENTIFIER$</crm:E41.Appellation>
    </crm:P1F.is_identified_by>

    <crm:P3F.has_note>
      <crm:E62.String>$OBJECT_NOTES$</crm:E62.String>
    </crm:P3F.has_note>

    <crm:P43.has_dimension>
      <crm:E54.Dimension>
        <crm:P2F.has_type rdf:resource="http://tempuri/diameter" />
        <crm:P91F.has_unit rdf:resource="http://tempuri/mm" />
        <crm:P90F.has_value>
          <crm:E60.Number>$MEASUREMENT_VALUE$</crm:E60.Number>
        </crm:P90F.has_value>
      </crm:E54.Dimension>
    </crm:P43.has_dimension>
  </crm:E19.PhysicalObject>

  <crm:E9.Move>
    <crm:P25F.moved rdf:resource="$OBJECT_URI$" />
    <crm:P26F.moved_to rdf:resource="$PLACE_URI$" />
  </crm:E9.Move>

</rdf:RDF>

```

Data template with defined placeholders

```

<?xml version="1.0"?>
<rdf:RDF
  xmlns:crm="http://cidoc.ics.forth.gr/rdfs/cidoc_v4.2.rdfs#"
  xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
  xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#">

  <crm:E19.PhysicalObject rdf:about="#e19.2652">
    <crm:P1F.is_identified_by>
      <crm:E41.Appellation>2652</crm:E41.Appellation>
    </crm:P1F.is_identified_by>

    <crm:P3F.has_note>
      <crm:E62.String>SF NO 427; FRENCH</crm:E62.String>
    </crm:P3F.has_note>

    <crm:P43.has_dimension>
      <crm:E54.Dimension>
        <crm:P2F.has_type rdf:resource="http://tempuri/diameter" />
        <crm:P91F.has_unit rdf:resource="http://tempuri/mm" />
        <crm:P90F.has_value>
          <crm:E60.Number>23</crm:E60.Number>
        </crm:P90F.has_value>
      </crm:E54.Dimension>
    </crm:P43.has_dimension>
  </crm:E19.PhysicalObject>

  <crm:E9.Move>
    <crm:P25F.moved rdf:resource="#e19.1650" />
    <crm:P26F.moved_to rdf:resource=" #e53.BA84-569" />
  </crm:E9.Move>

</rdf:RDF>

```

Resultant output (per row)

# Linked data issues in STELLAR

- What parts of dataset useful to map/extract for linked data purposes?  
What best left as native dataset? Cost/benefit ?
- Lack of current domain name for some organisations within project  
premature/temporary URI definition?
- Lack of resource commitment for some organisations within project  
Where data reside? Demands on server?
- Relationship between local dataset glossaries and 'centre'
  - map to unified central super glossary?
  - maintain local glossaries with (SKOS) mappings to centre?
- Resultant application?  
Linked data in itself not offer search capability

# Mapping issues

- Potentially multiple mappings can exist to a broad conceptual framework (BRICKS experience)
  - depends on purpose for mapping and focus of concern
  - STELLAR design mapping patterns (ontology → datasets)
- Datasets encountered not have a schema, not necessarily well structured and probably need semantic cleaning
  - ==> infer schema for tool purposes from dataset



# Mapping issues ctd.

Considering various cases of mapping RDB to CRM

- DB column to CRM entity
- DB column to multiple CRM entities
- DB column to CRM entity with intermediate (event) nodes
- DB columns (in same table) concatenated to single CRM entity
- DB complete Table maps to a single CRM entity
- DB entities map to CRM entity plus set of properties

# CRM is complex => need for simpler views

- CRM useful for integration and semantic interoperability  
Not mirror RDF structure in RDF
- It is not necessary to present the user with full CRM or CRM-EH views for mapping work and search (browsing) interfaces
- Search / browsing / mapping interfaces can present a simplified CRM view to user, while retaining the benefits of CRM standard for inter-operability

# References

1. STAR Project. <http://hypermedia.research.glam.ac.uk/kos/star/>
2. STAR Project Publications. <http://hypermedia.research.glam.ac.uk/publications/#kos>
3. STELLAR Project . <http://hypermedia.research.glam.ac.uk/kos/stellar>