Dynamic Linked Cells:
An Implementation of "Virtual Objects" in DOORS

Michael Sutherland
Galactic Solutions Group, LLC
Michael.Sutherland@galactic-solutions.com

Prepared for the **Telelogic Americas 2006 User Group Conference**

http://www.telelogic.com/campaigns/2006/americas/ugc/index.cfm
23 October 2006

Abstract:

DOORS has the ability to link an object in one module to an object in another module. The text and attributes from the other object can be viewed in a separate column via "Layout DXL", but cannot be incorporated into the main column of the DOORS module.
A technique called "Dynamic Linked Cells" will be demonstrated which allows the addition of "Virtual Objects" into the main column of a DOORS module. This technique has the following benefits:

(1) Cell is automatically updated when the data is changed at the source.

(2) Cell appears in "main" column, and data exports to Word or Excel.

(3) Cell is not editable, and the data can only be changed at the source.

(4) Data is mastered in one location and can be referenced in multiple locations.

(5) Cells do not update after baselining, preserving the state of the data.

(6) Cells retain their data when the module is archived and moved to another database.

(7) Multiple attributes can be shown in the same cell.

The technical details of the development of the "Dynamic Linked Cells" application will be discussed, and the full DXL source code for the implementation will be made available to attendees.

Author Biography:

Michael Sutherland is the founder of Galactic Solutions Group, and has 16 years experience working with the automotive and military industries. Michael was a consultant to General Motors Powertrain and Manufacturing for 11 years. He is currently working with General Dynamics on the Future Combat Systems project, developing and deploying Systems Engineering processes and tools. Michael has a Masters Degree in Electrical and Computer Engineering from Oakland University in Rochester MI. He also specializes in the application of the DOORS database, mentoring and teaching application, customization (DXL), and information modeling to a wide variety of clients across the United States.

Background:

On a complex product development project, high-level requirements for the system are developed and decomposed into derived requirements for subsystems and components. Lower-level specifications for requirements, design, and interface specifications need to reference data from high level specifications.

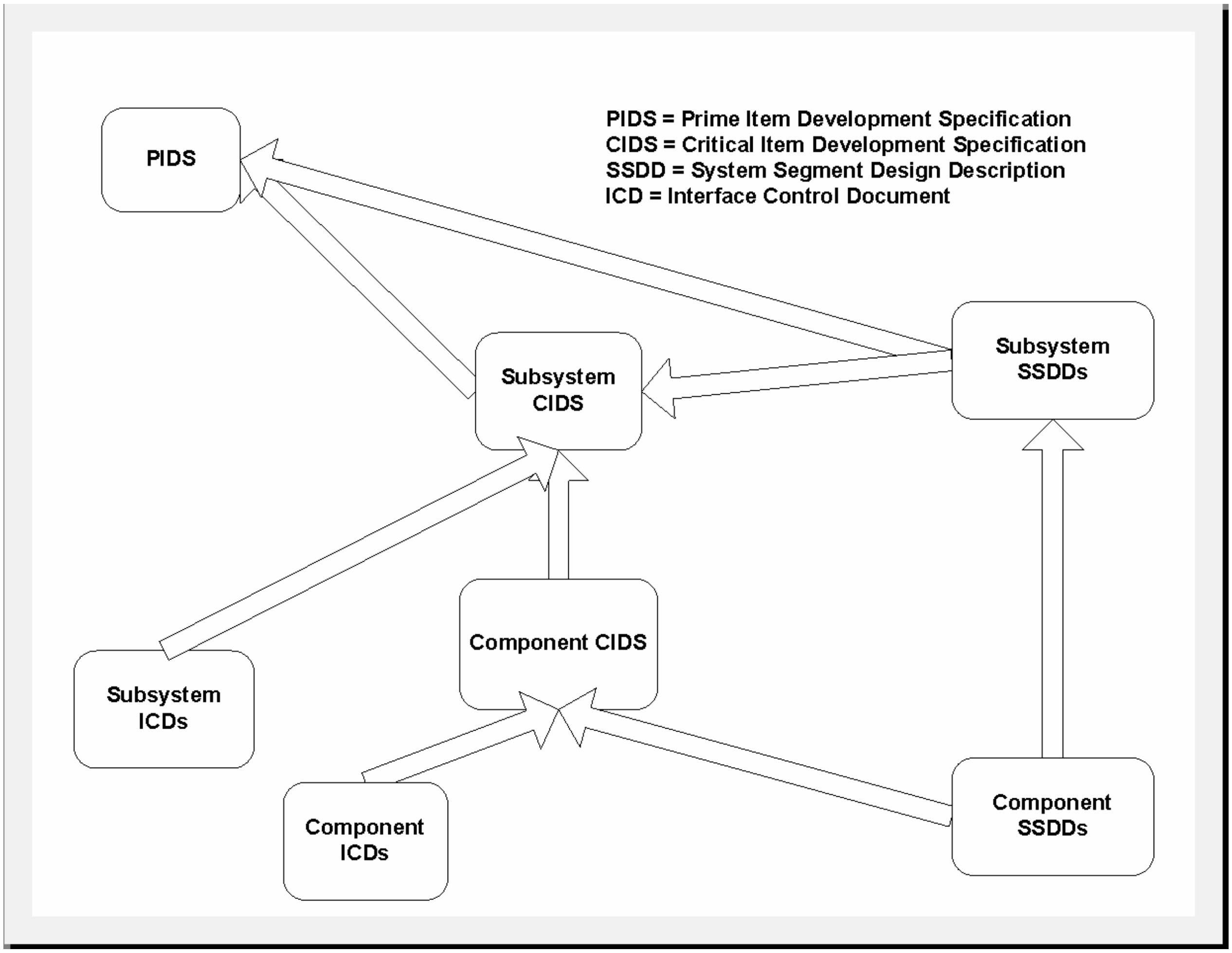

PIDS = Prime Item Development Specification
CIDS = Critical Item Development Specification
SSDD = System Segment Design Description
ICD = Interface Control Document
PIDS
Subsystem CIDS
Subsystem SSDDs
Component CIDS
Subsystem ICDs
Component ICDs
Component SSDDs

Figure 1: Product Specifications

DOORS uses links to associate data in one Module with data in another Module. Layout DXL in a column can "pull" the data from the one module to the other dynamically. This data does not appear in the DOORS "main" column. Instead, the data appears in a separate column. The data exports to Word "Book" form as an attribute, in the following format:

"Layout Column Name : Layout Column Data"

Assigned "Paragraph Style" is ignored for Word style formatting.

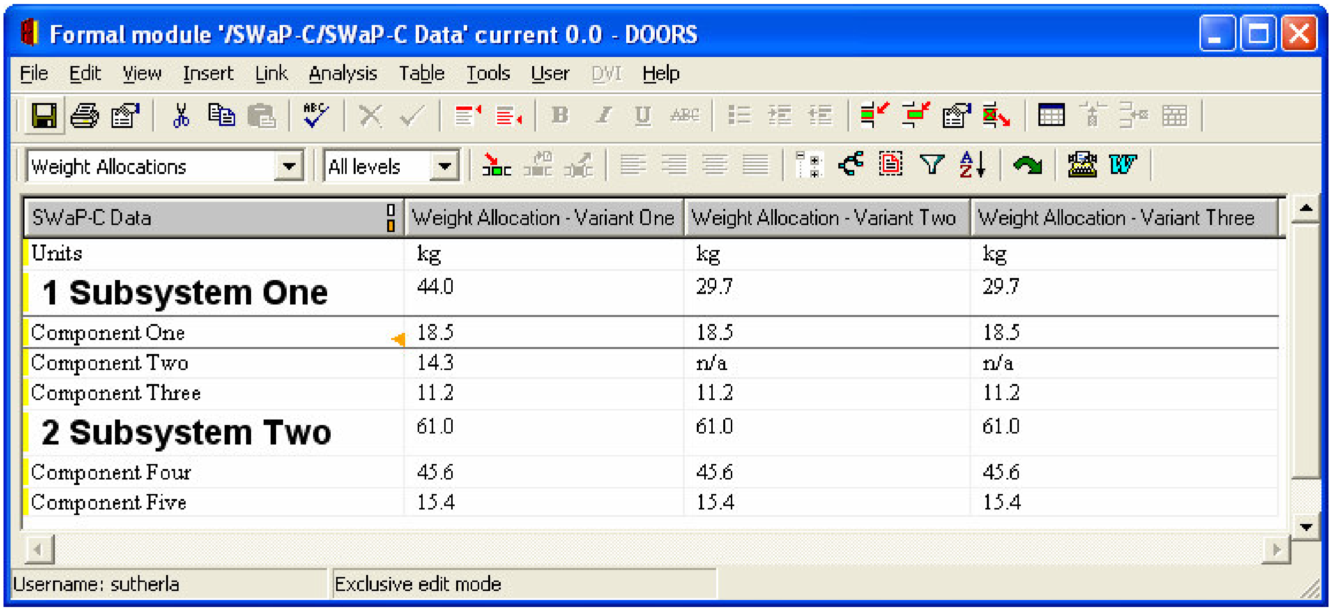
Since this data is not actually written to the module, DOORS archives do not contain the data when they are restored in another database.

"Dynamic Linked Cells"

To solve these issues, a technique called "Dynamic Linked Cells" was developed in DOORS to allow "Virtual Objects" to be created that dynamically update their content by following an out-link to a target object, and copying the data to a DOORS table cell in the DOORS "main" column.

Application: Managing SWaP-C Data

SWaP-C (Size, Weight, Power, and Cooling) allocation and estimate data is tracked for each subsystem and component of the product, and is referenced in many specifications. Placing this data in single DOORS module, and using Dynamic Linked Cells to reference the data, allows each specification to be automatically kept up to date and synchronized with the master SWaP-C data table. The SWaP-C data table is composed of rows and columns, where the rows are the subsystems and components which are represented as DOORS objects, and the columns are the SWaP-C data which is represented as DOORS attributes


Formal module '/SWaP-C/SWaP-C Data' current 0.0 - DOORS
File Edit View Insert Link Analysis Table Tools User DVI Help
Weight Allocations
All levels
Username: sutherla
Exclusive edit mode

SWaP-C Data	Weight Allocation - Variant One	Weight Allocation - Variant Two	Weight Allocation - Variant Three
Units	kg	kg	kg
1 Subsystem One	44.0	29.7	29.7
Component One	18.5	18.5	18.5
Component Two	14.3	n/a	n/a
Component Three	11.2	11.2	11.2
2 Subsystem Two	61.0	61.0	61.0
Component Four	45.6	45.6	45.6
Component Five	15.4	15.4	15.4

Figure 2: SWaP-C Weight Allocation Table

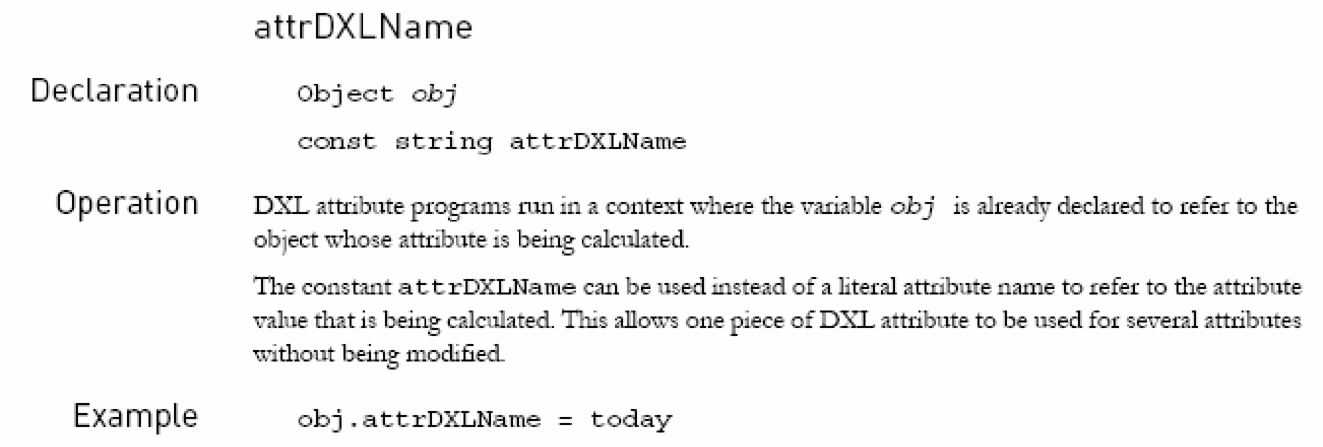
Implementation:

The goal is to implement a method to allow specifications to reference data "cells" in DOORS modules, and keep the data updated.

The implementation of "Dynamic Linked Cells" combines three unique features of DOORS, Attribute DXL, the Attribute property of DOORS Tables, and Link Attributes.

Attribute DXL:

DOORS allows “Attribute DXL” code to be associated with an attribute. Attribute DXL updates the values of the attribute for objects in the module when a module is opened, or when a user selects “Tools -> Refresh DXL Attributes” in a Module window. Attribute DXL uses two pre-declared variables (attrDXLName, obj) to determine what attribute is being updated, and what object is being updated for each execution of the code:



attrDXLName

Declaration

```
Object obj
const string attrDXLName
```

Operation

DXL attribute programs run in a context where the variable *obj* is already declared to refer to the object whose attribute is being calculated.

The constant `attrDXLName` can be used instead of a literal attribute name to refer to the attribute value that is being calculated. This allows one piece of DXL attribute to be used for several attributes without being modified.

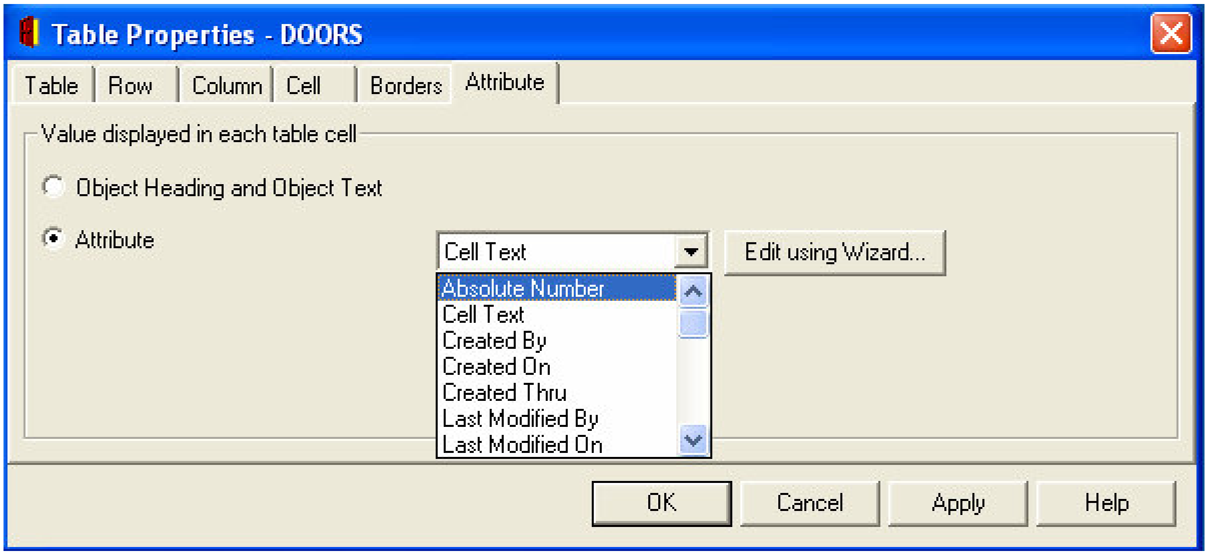
Example

```
obj.attrDXLName = today
```

Figure 3: Attribute DXL - Pre-Declared Variables

Table Properties - Attribute:

A DOORS table is composed of DOORS objects that have attributes. A DOORS table has a property that specifies the value of the attribute to be displayed in the table cell. This attribute can have associated Attribute DXL.



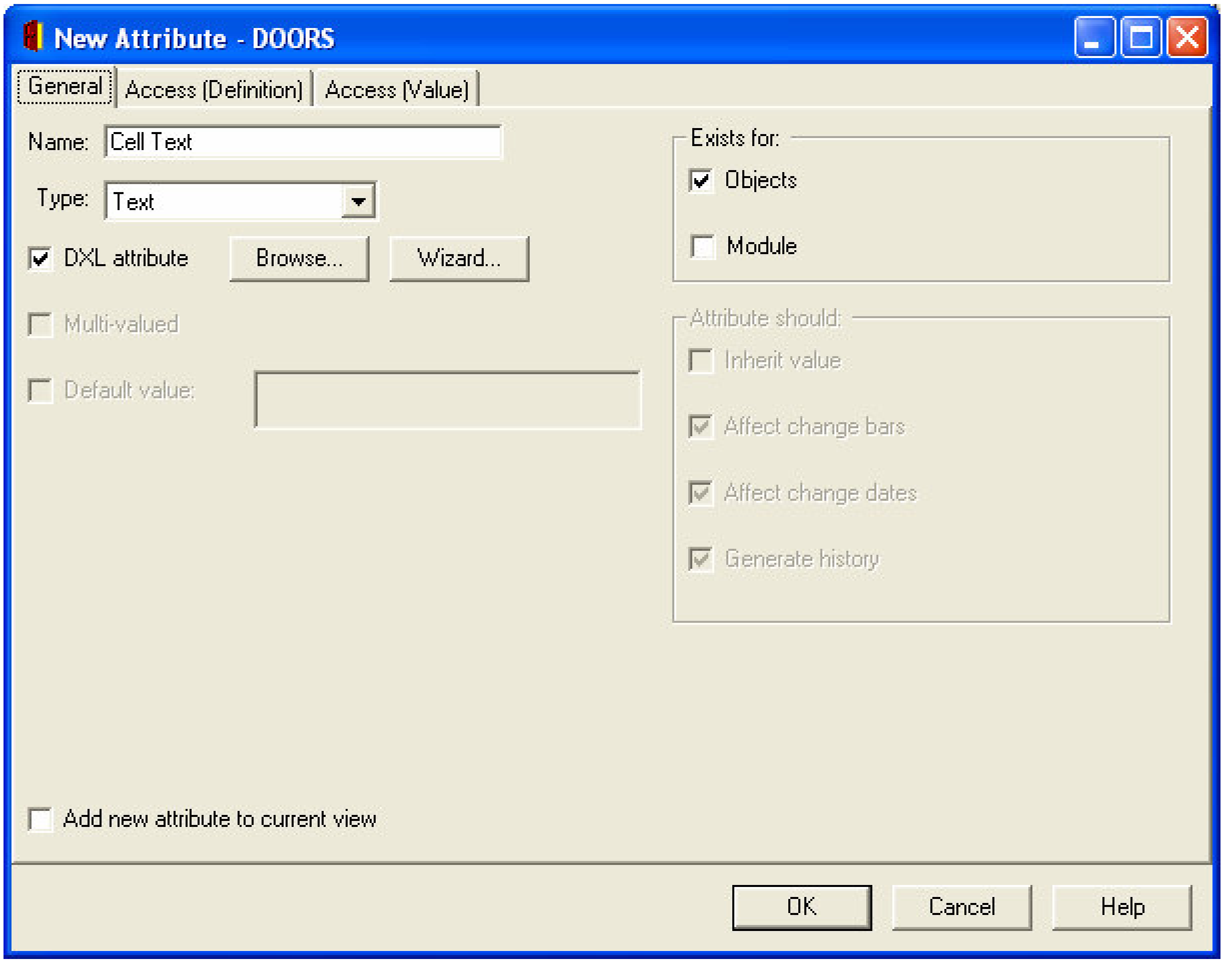
Value displayed in each table cell

○ Object Heading and Object Text

● Attribute: Cell Text

Figure 4: DOORS Table Properties – Attribute Tab

Attribute DXL can be written to follow a link out of a table cell, and copy data from the target Object. This technique was used to create an implementation of “Dynamic Linked Cells.” A DXL attribute called “Cell Text” is created.



Name: Cell Text

Type: Text

☑ DXL attribute

□ Multi-valued

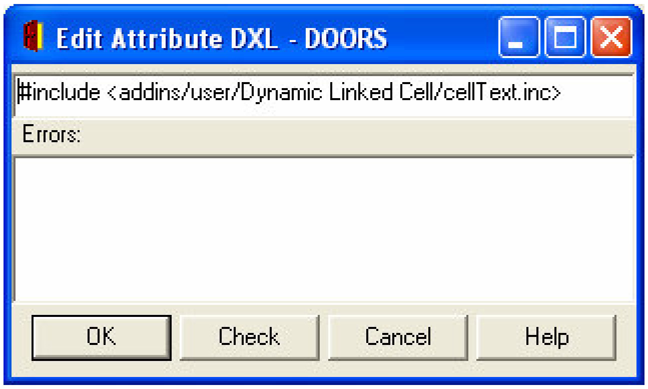
□ Default value:

Exists for:
☑ Objects
□ Module

Attribute should:
□ Inherit value
☑ Affect change bars
☑ Affect change dates
☑ Generate history

□ Add new attribute to current view

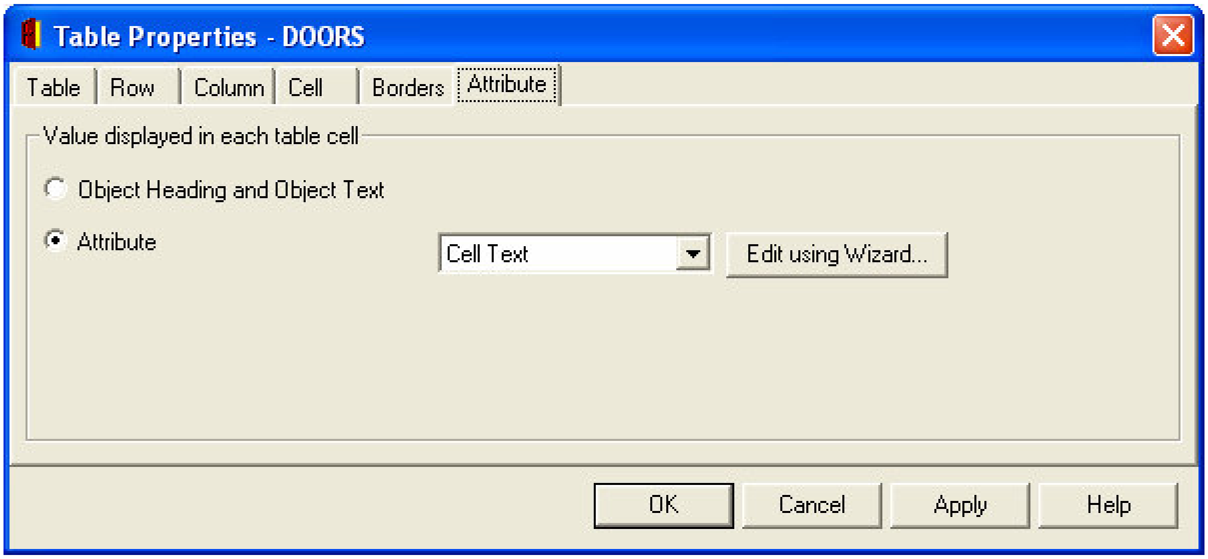
Figure 5: Attribute Definition for Cell Text Attribute



```
#include <addins/user/Dynamic Linked Cell/cellText.inc>
```

Figure 6: Attribute DXL inclusion for “Cell Text” Attribute

Each “Dynamic Linked Cell” uses this “Cell Text” attribute.



Value displayed in each table cell

○ Object Heading and Object Text

● Attribute: Cell Text

Figure 7: Table Properties and “Cell Text” Attribute

To facilitate ease of use when creating a “Dynamic Linked Cell”, “Insert Dynamic Linked Cell” DXL functionality has been created to automate these steps for the user. This DXL functionality creates the cell, removes cell borders, sizes the cell, and sets the attribute property for the table to the “Cell Text” attribute.

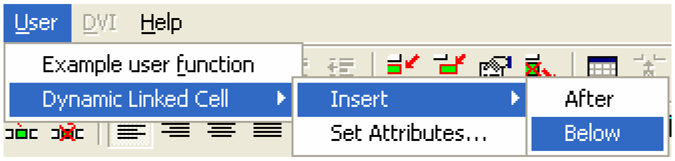
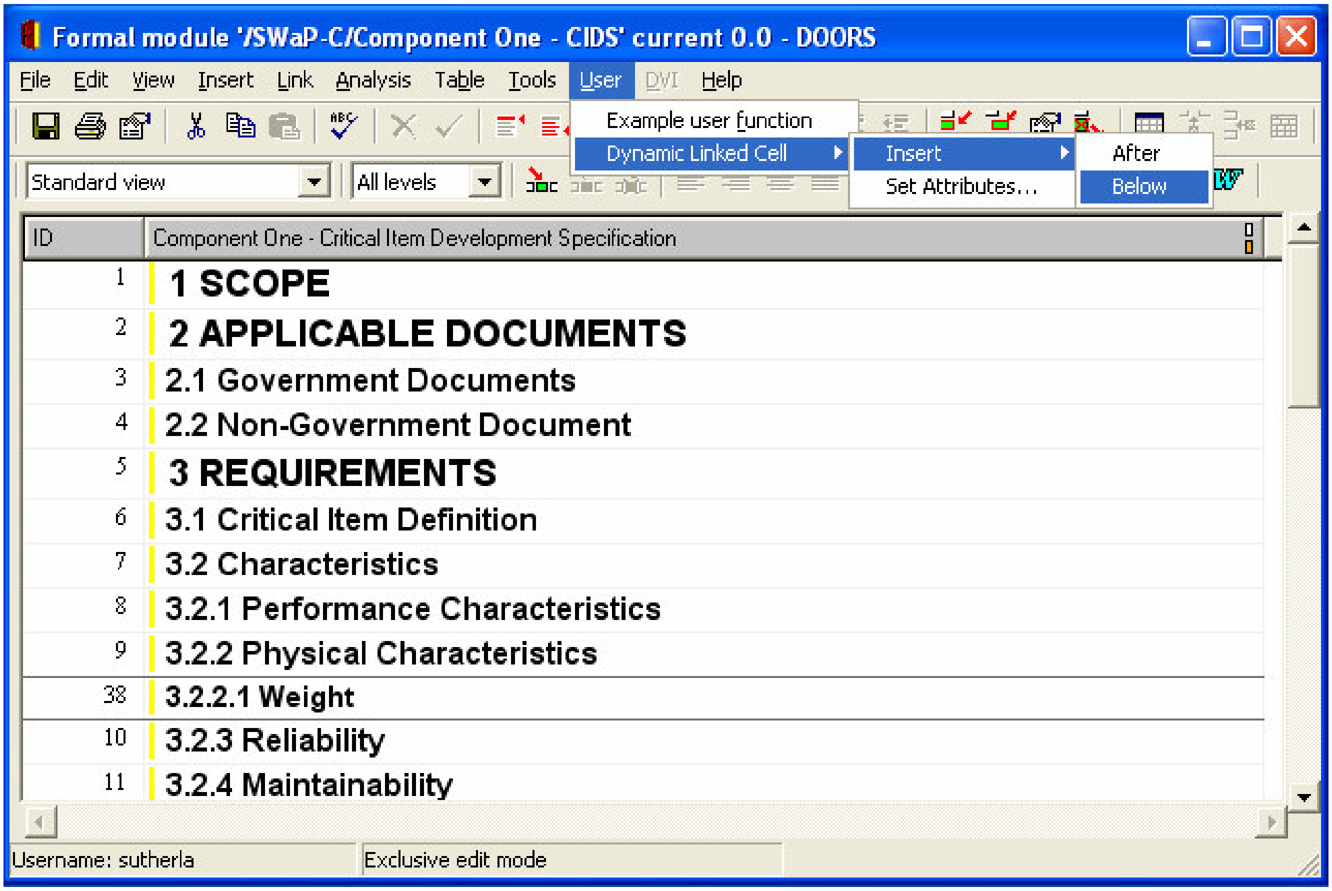


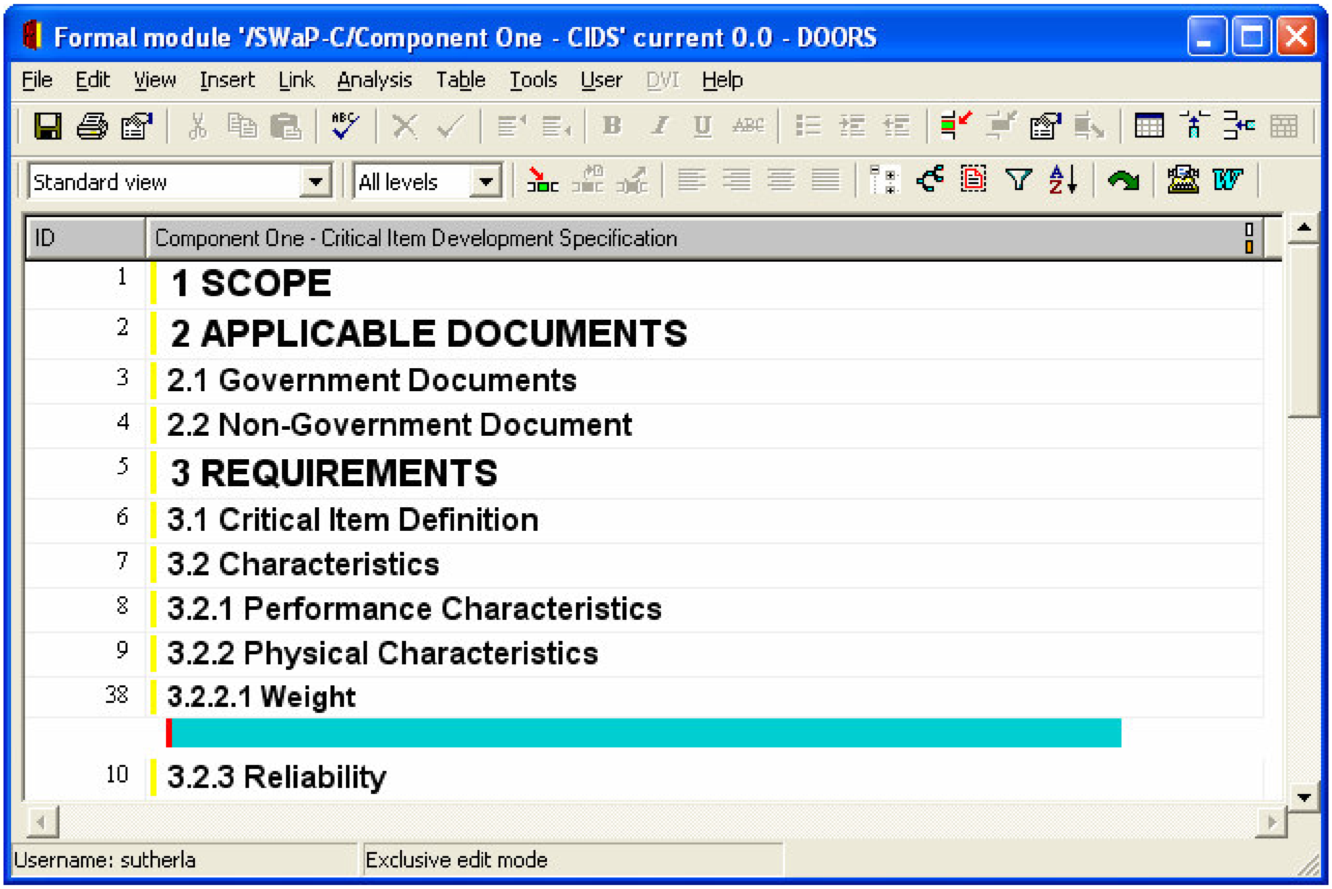
Figure 8: Insert Dynamic Linked Cell – Insert Menu Functions



ID	Component One - Critical Item Development Specification
1	1 SCOPE
2	2 APPLICABLE DOCUMENTS
3	2.1 Government Documents
4	2.2 Non-Government Document
5	3 REQUIREMENTS
6	3.1 Critical Item Definition
7	3.2 Characteristics
8	3.2.1 Performance Characteristics
9	3.2.2 Physical Characteristics
38	3.2.2.1 Weight
10	3.2.3 Reliability
11	3.2.4 Maintainability

Figure 9: "Dynamic Linked Cell" – Before Insert

The automatic removal of the cell borders makes the cell appear native to the DOORS "main" column.

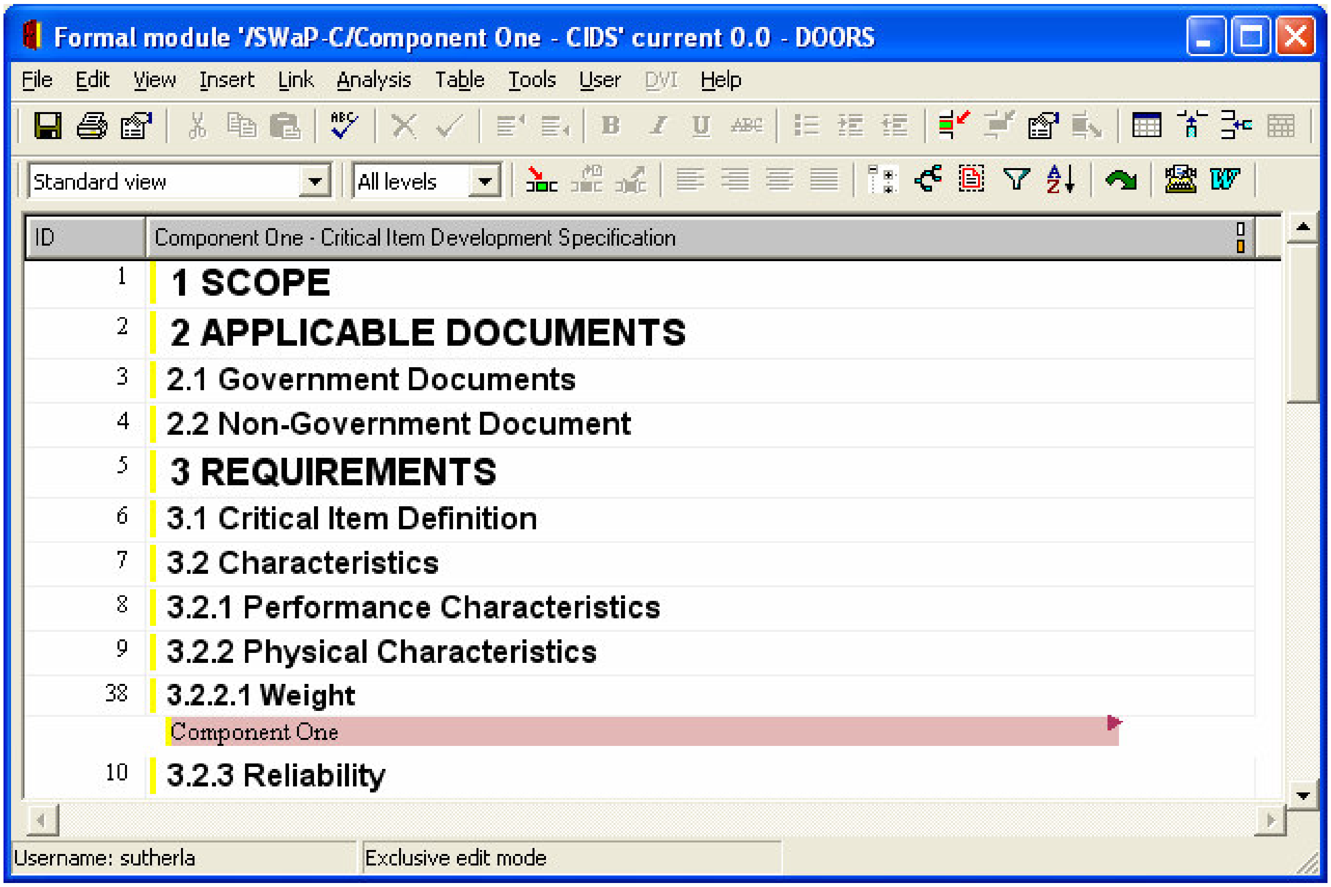

Formal module '/SWaP-C/Component One - CIDS' current 0.0 - DOORS
File Edit View Insert Link Analysis Table Tools User DVI Help
Standard view
All levels

ID	Component One - Critical Item Development Specification
1	1 SCOPE
2	2 APPLICABLE DOCUMENTS
3	2.1 Government Documents
4	2.2 Non-Government Document
5	3 REQUIREMENTS
6	3.1 Critical Item Definition
7	3.2 Characteristics
8	3.2.1 Performance Characteristics
9	3.2.2 Physical Characteristics
38	3.2.2.1 Weight
10	3.2.3 Reliability

Username: sutherla | Exclusive edit mode

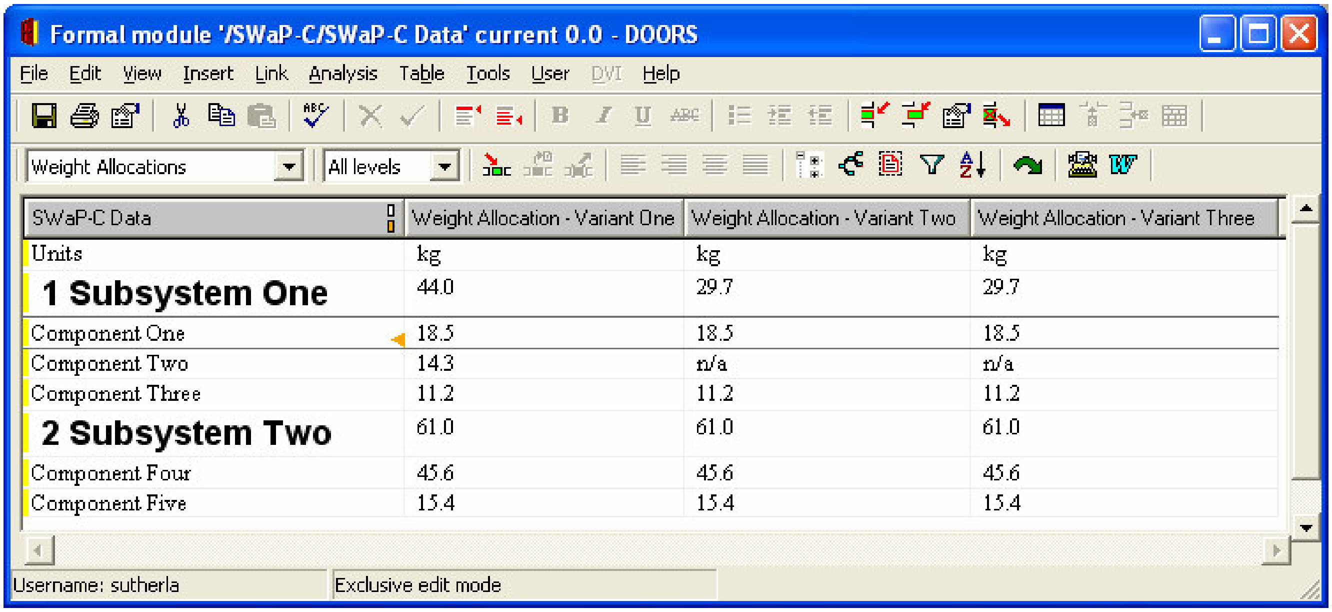
Figure 10: "Dynamic Linked Cell" – After Insert

Once the "Dynamic Linked Cell" is inserted, the user creates a link to the target object. Refreshing DXL attributes will perform the initial pull and population of the data.


Formal module '/SWaP-C/Component One - CIDS' current 0.0 - DOORS
File Edit View Insert Link Analysis Table Tools User DVI Help
Standard view
All levels
Username: sutherla
Exclusive edit mode

ID	Component One - Critical Item Development Specification
1	1 SCOPE
2	2 APPLICABLE DOCUMENTS
3	2.1 Government Documents
4	2.2 Non-Government Document
5	3 REQUIREMENTS
6	3.1 Critical Item Definition
7	3.2 Characteristics
8	3.2.1 Performance Characteristics
9	3.2.2 Physical Characteristics
38	3.2.2.1 Weight
	Component One
10	3.2.3 Reliability

Figure 11: “Dynamic Linked Cell” after link creation


Formal module '/SWaP-C/SWaP-C Data' current 0.0 - DOORS
File Edit View Insert Link Analysis Table Tools User DVI Help
Weight Allocations
All levels
Username: sutherla
Exclusive edit mode

SWaP-C Data	Weight Allocation - Variant One	Weight Allocation - Variant Two	Weight Allocation - Variant Three
Units	kg	kg	kg
1 Subsystem One	44.0	29.7	29.7
Component One	18.5	18.5	18.5
Component Two	14.3	n/a	n/a
Component Three	11.2	11.2	11.2
2 Subsystem Two	61.0	61.0	61.0
Component Four	45.6	45.6	45.6
Component Five	15.4	15.4	15.4

Figure 12: SWaP-C – Referenced Row after link creation

Attribute Selection:

A user of “Dynamic Linked Cells” may want to reference more data than just the DOORS “Main” Column (Object Heading and Object Text). To achieve this, Link Attributes are used to store the attribute names.

Link Attributes can be created from the “Edit -> Attributes…” menu in a Link Module:

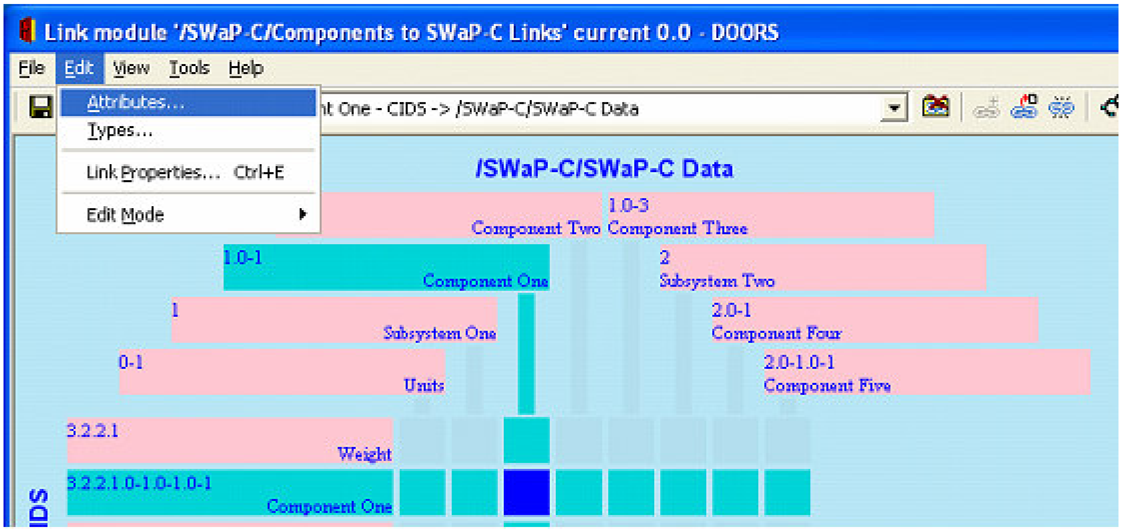
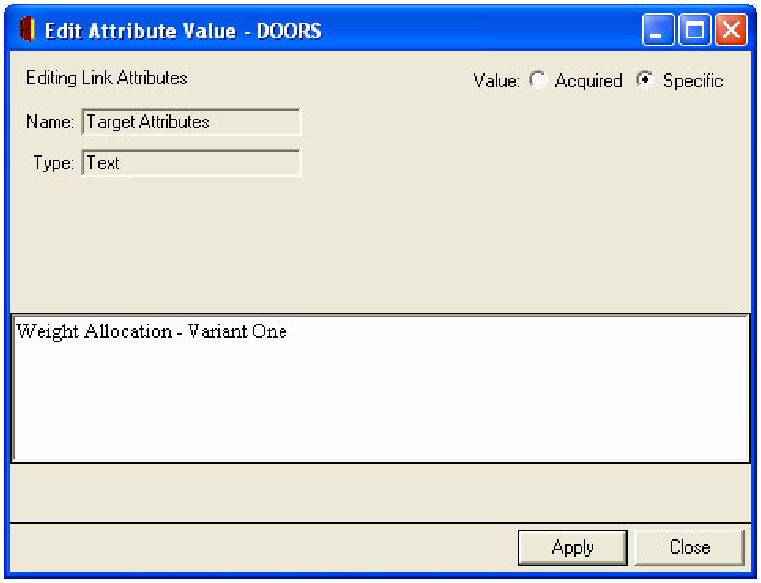


Figure 13: Link Module – Create Link Attributes

A link attribute named “Target Attributes” is defined and used in link modules containing links from “Dynamic Linked Cells” to the referenced target data. The link references the entire row, and the attribute name allows the “Dynamic Linked Cell” to target a specific “Cell” (object/attribute combination) in a DOORS module.

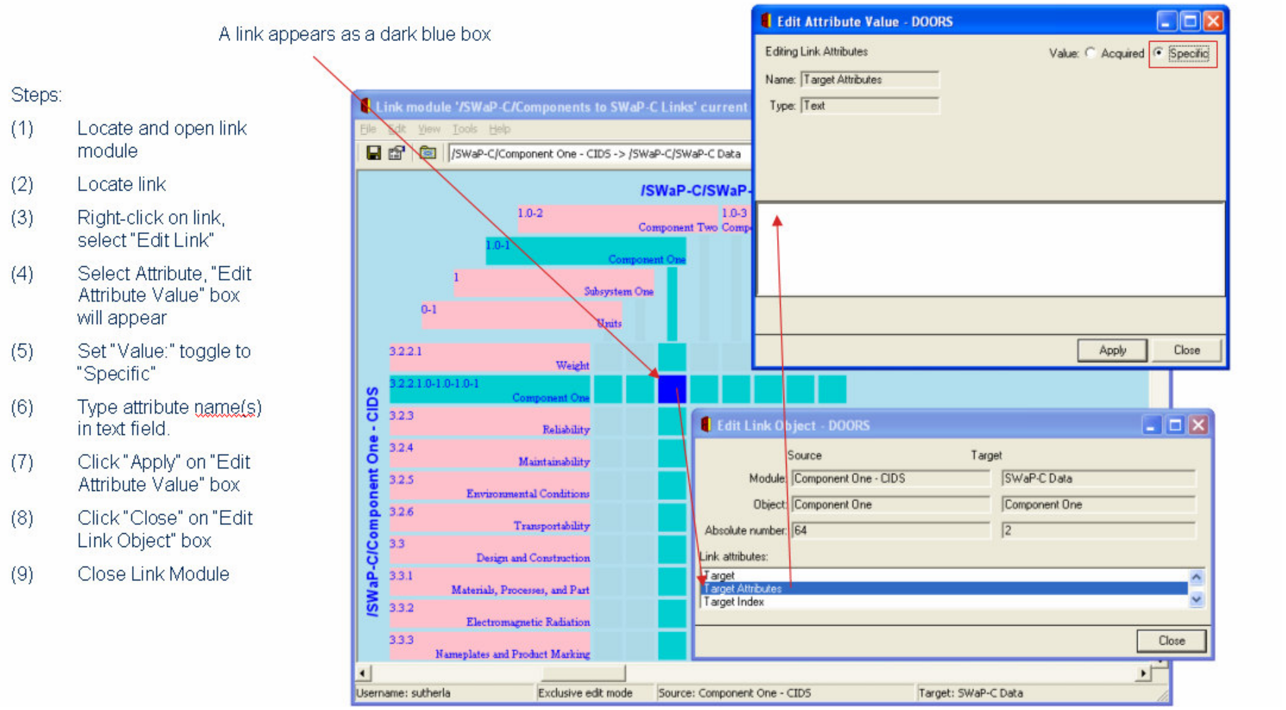


Name: Target Attributes
Type: Text
Value: ○ Acquired ● Specific

Weight Allocation - Variant One

Figure 14: Link Module – Edit Link Attribute Value

Editing link attributes through the link module is a complicated, multi-step process.



A link appears as a dark blue box

Steps:

(1) Locate and open link module

(2) Locate link

(3) Right-click on link, select "Edit Link"

(4) Select Attribute, "Edit Attribute Value" box will appear

(5) Set "Value:" toggle to "Specific"

(6) Type attribute name(s) in text field.

(7) Click "Apply" on "Edit Attribute Value" box

(8) Click "Close" on "Edit Link Object" box

(9) Close Link Module

Edit Attribute Value - DOORS

Editing Link Attributes — Value: ○ Acquired ● Specific

Name: Target Attributes

Type: Text

Link module '/SWaP-C/Components to SWaP-C Links' current

/SWaP-C/Component One - CIDS -> /SWaP-C/SWaP-C Data

Edit Link Object - DOORS

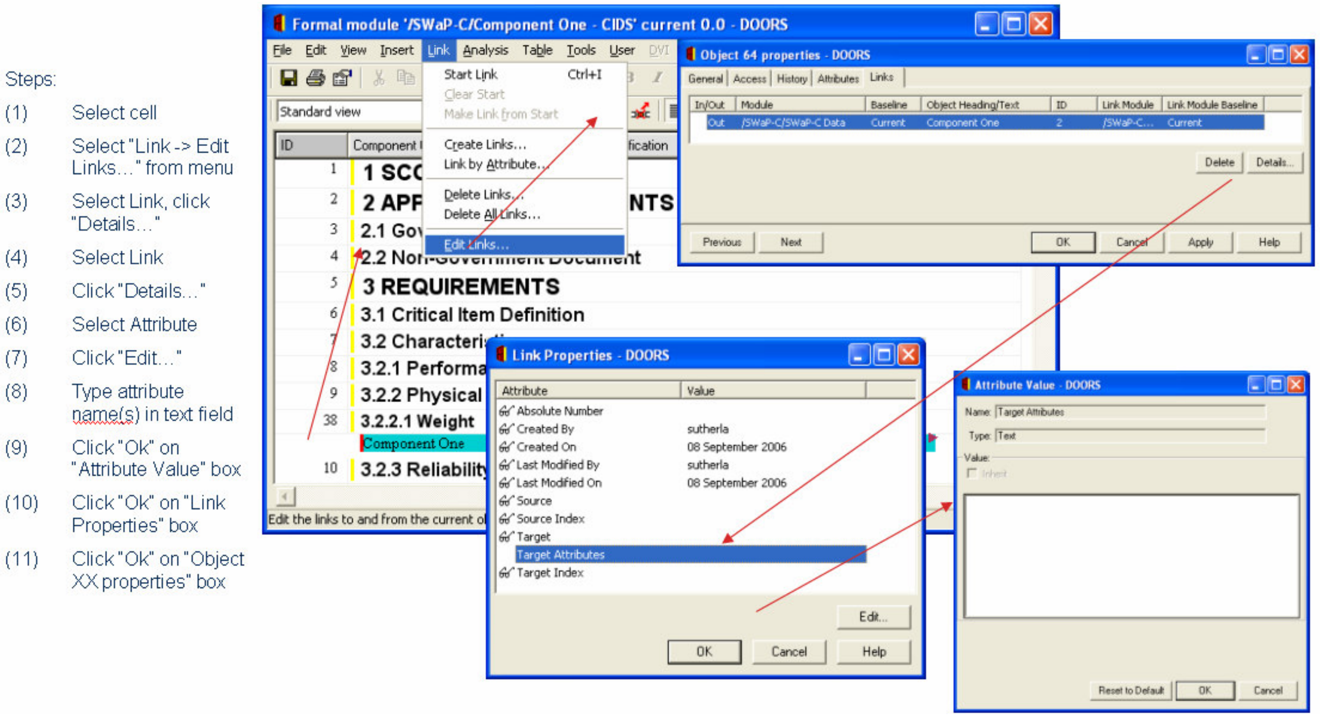
	Source	Target
Module:	Component One - CIDS	SWaP-C Data
Object:	Component One	Component One
Absolute number:	64	2

Link attributes: Target, Target Attributes, Target Index

Username: sutherla — Exclusive edit mode — Source: Component One - CIDS — Target: SWaP-C Data

Figure 15: Edit Link Attribute Value – Link Module

Editing link attributes through the source module is a complicated, multi-step process.



Steps:

(1) Select cell

(2) Select "Link -> Edit Links…" from menu

(3) Select Link, click "Details…"

(4) Select Link

(5) Click "Details…"

(6) Select Attribute

(7) Click "Edit…"

(8) Type attribute name(s) in text field

(9) Click "Ok" on "Attribute Value" box

(10) Click "Ok" on "Link Properties" box

(11) Click "Ok" on "Object XX properties" box

Formal module '/SWaP-C/Component One - CIDS' current 0.0 - DOORS

Object 64 properties - DOORS

In/Out	Module	Baseline	Object Heading/Text	ID	Link Module	Link Module Baseline
Out	/SWaP-C/SWaP-C Data	Current	Component One	2	/SWaP-C...	Current

Link Properties - DOORS

Attribute	Value
Absolute Number	
Created By	sutherla
Created On	08 September 2006
Last Modified By	sutherla
Last Modified On	08 September 2006
Source	
Source Index	
Target	
Target Attributes	
Target Index	

Attribute Value - DOORS

Name: Target Attributes

Type: Text

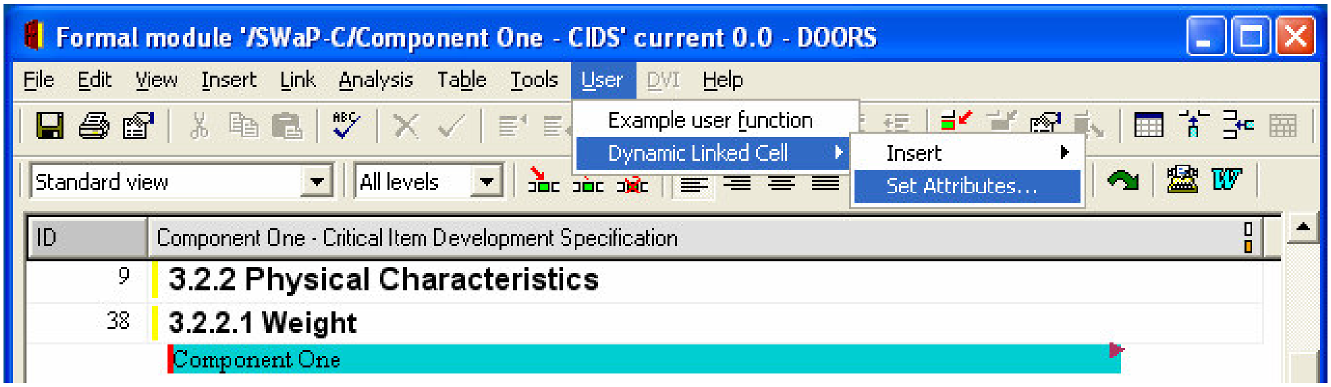
Value: □ Inherit

Edit the links to and from the current object

Figure 16: Edit Link Attribute Value – Source Module

Set Attributes… Function:

Because editing link attributes from the DOORS user interface is a complicated, multi-step process, and typing attributes names is prone to error and inconsistency, a “Set Attributes…” function was developed as part of the Dynamic Linked Cell implementation.



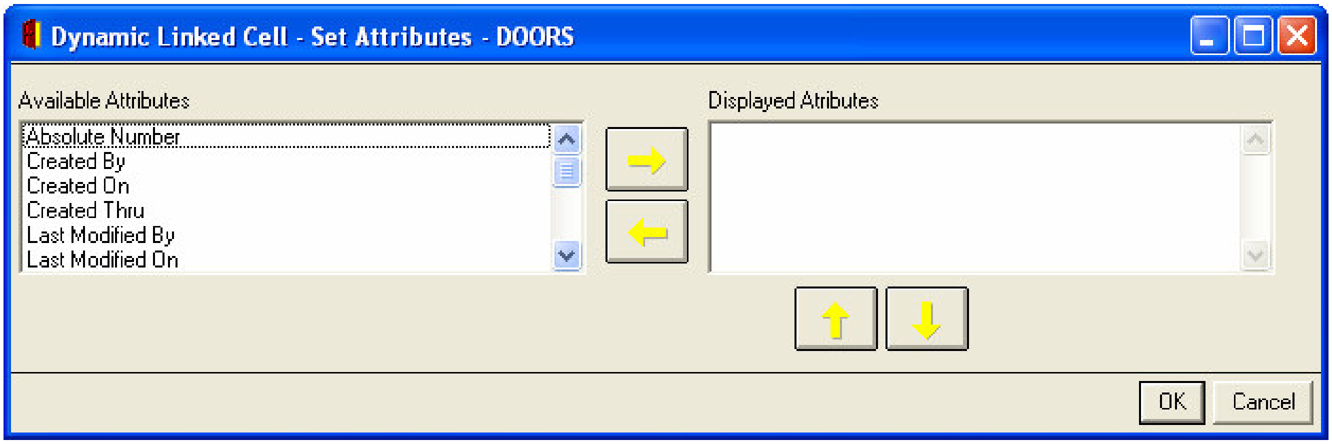
9 3.2.2 Physical Characteristics

38 3.2.2.1 Weight

Component One

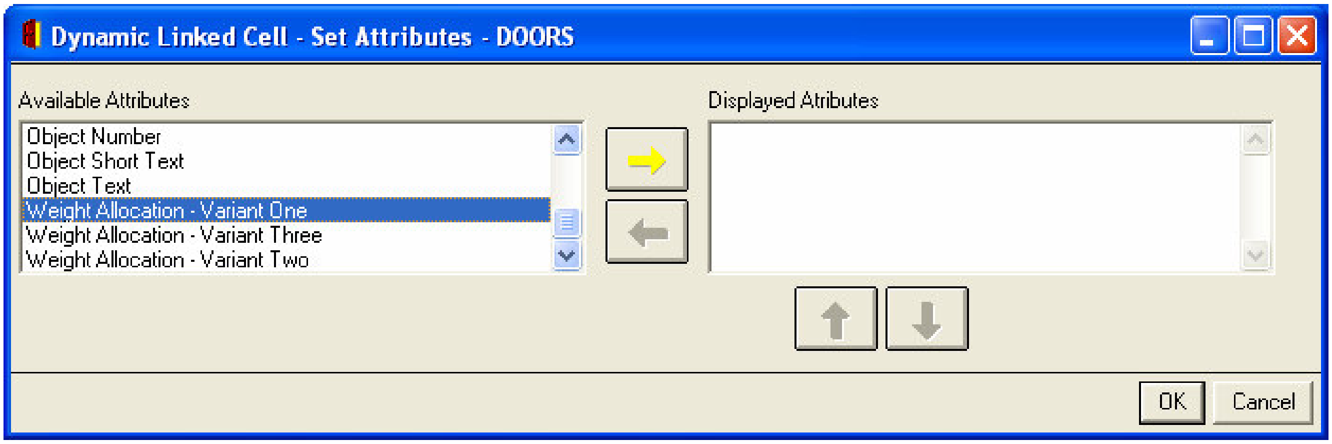
Figure 17: Menu Selection – “Dynamic Linked Cell -> Set Attributes…”

The “Set Dynamic Linked Cell Attributes” function scans the target module, and displays a list of attributes available in the target module.



The user can then select attributes and “push” them over to the “Displayed Attributes” list. This list determines the attribute content and order for the “Dynamic Linked Cell”.

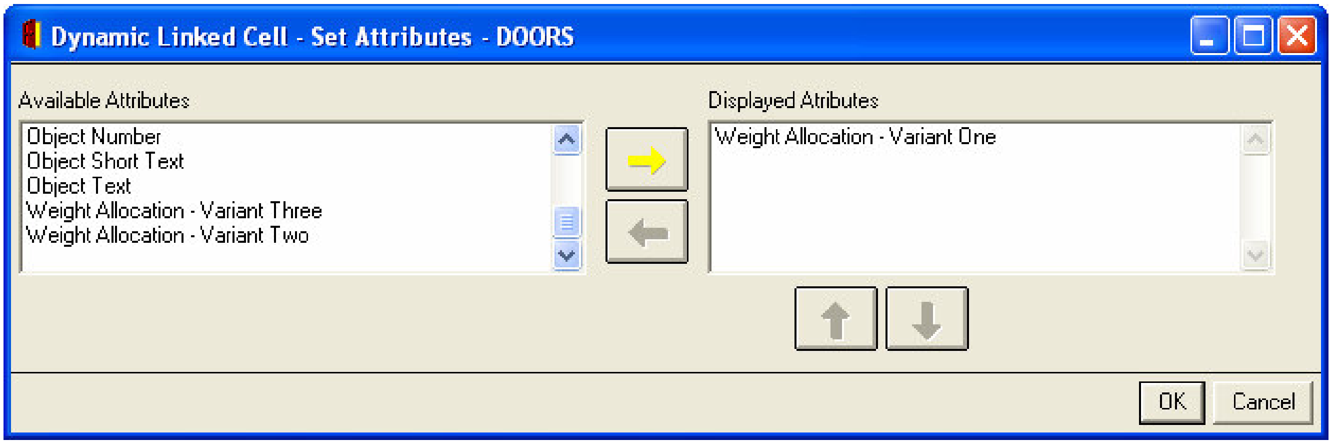
Figure 18: “Dynamic Linked Cell -> Set Attributes…” – Attribute Selection



Available Attributes:

- Object Number
- Object Short Text
- Object Text
- Weight Allocation - Variant One
- Weight Allocation - Variant Three
- Weight Allocation - Variant Two

Figure 19: “Dynamic Linked Cell -> Set Attributes…” – Attribute Selected



Available Attributes:

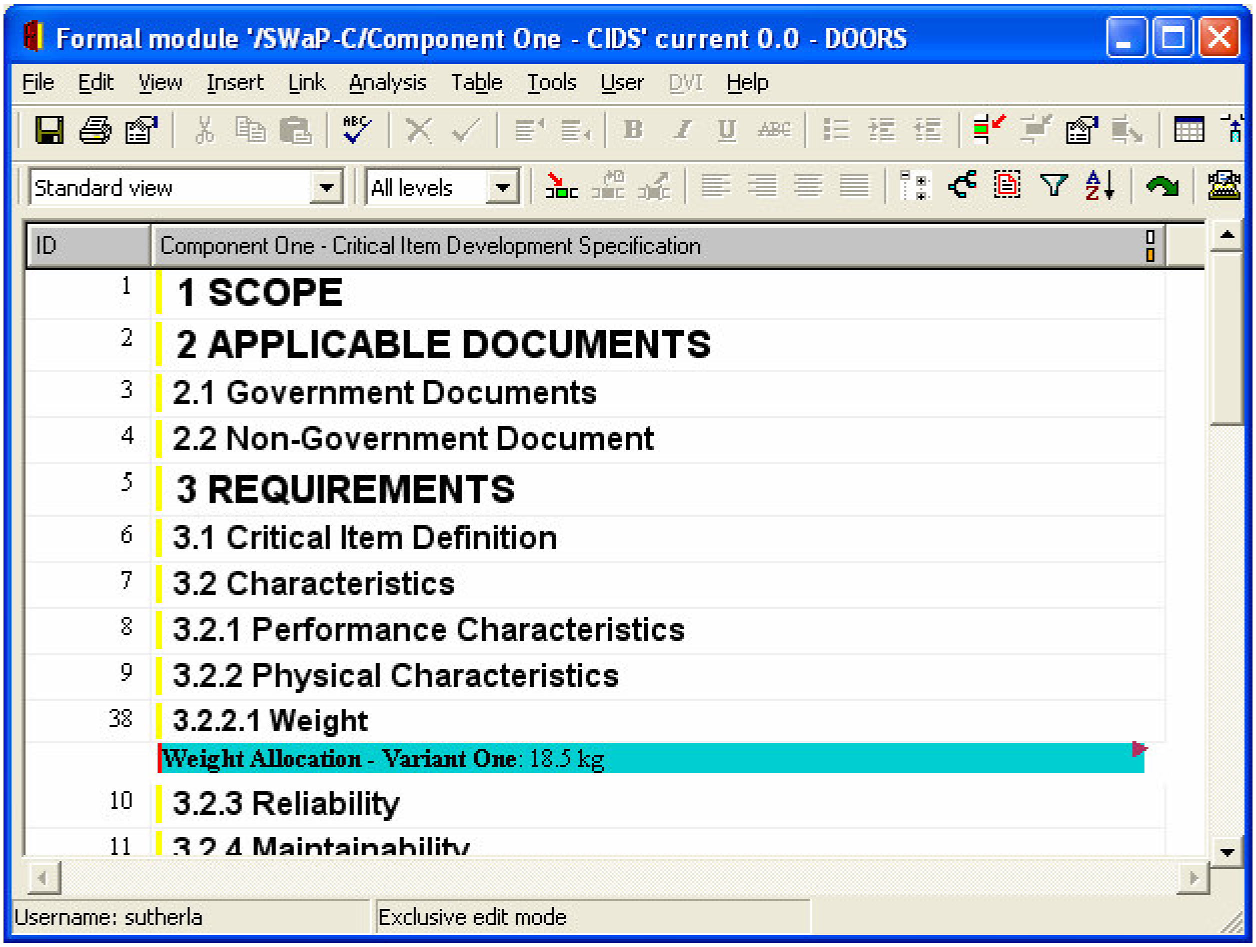
- Object Number
- Object Short Text
- Object Text
- Weight Allocation - Variant Three
- Weight Allocation - Variant Two

Displayed Atributes:

- Weight Allocation - Variant One

Figure 20: “Dynamic Linked Cell -> Set Attributes…” – Attribute Displayed

Once the dialog box is closed, the updates will be applied, and the new data will be pulled. Attributes names will appear in bold, followed by the attribute value.

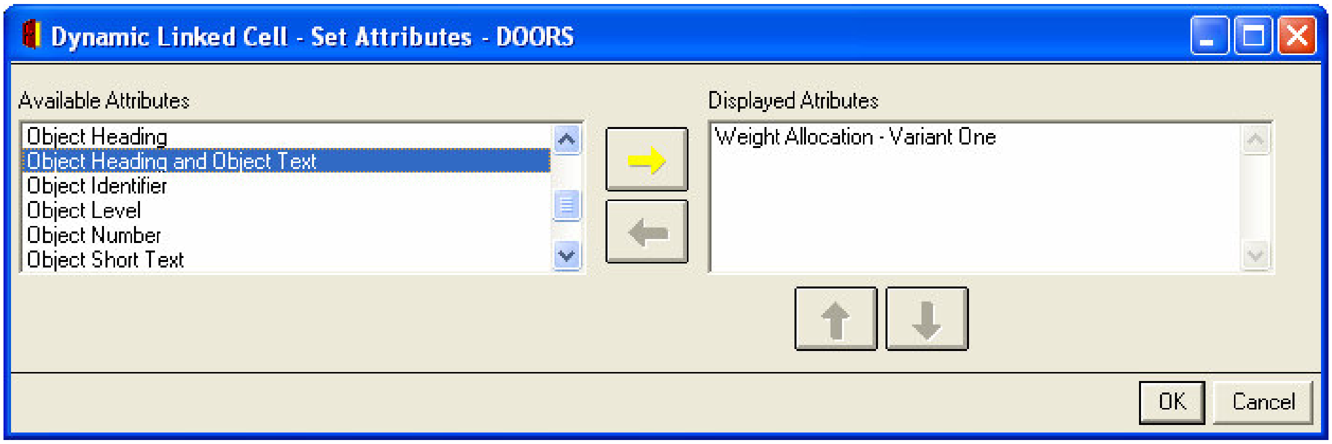


Formal module '/SWaP-C/Component One - CIDS' current 0.0 - DOORS
File Edit View Insert Link Analysis Table Tools User DVI Help
Standard view
All levels
Username: sutherla
Exclusive edit mode

ID	Component One - Critical Item Development Specification
1	1 SCOPE
2	2 APPLICABLE DOCUMENTS
3	2.1 Government Documents
4	2.2 Non-Government Document
5	3 REQUIREMENTS
6	3.1 Critical Item Definition
7	3.2 Characteristics
8	3.2.1 Performance Characteristics
9	3.2.2 Physical Characteristics
38	3.2.2.1 Weight
	Weight Allocation - Variant One: 18.5 kg
10	3.2.3 Reliability
11	3.2.4 Maintainability

Figure 21: “Dynamic Linked Cell” –Attribute Display

A special attribute called “Object Heading and Object Text” is available in the list of available attributes. This is to pull the data from the DOORS “main” column, and is represented without an attribute label. This can be commingled with other attributes in any order.

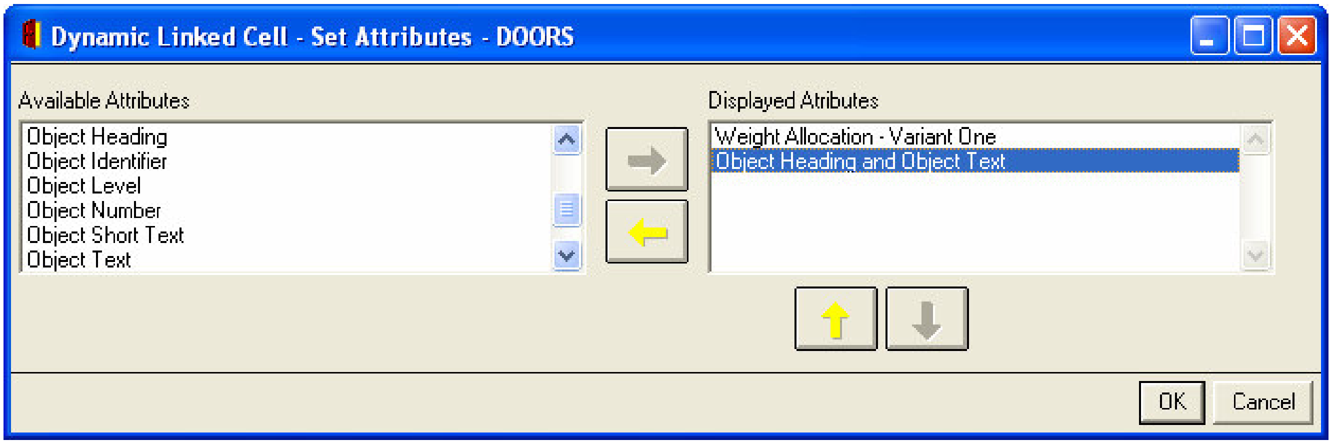


Available Attributes:
- Object Heading
- Object Heading and Object Text
- Object Identifier
- Object Level
- Object Number
- Object Short Text

Displayed Atributes:
- Weight Allocation - Variant One

Figure 22: “Dynamic Linked Cell -> Set Attributes…” – “Object Heading and Object Text” Selected

The “Object Heading and Object Text” attribute can be “pushed” over to the Displayed Attribute list using the left arrow.

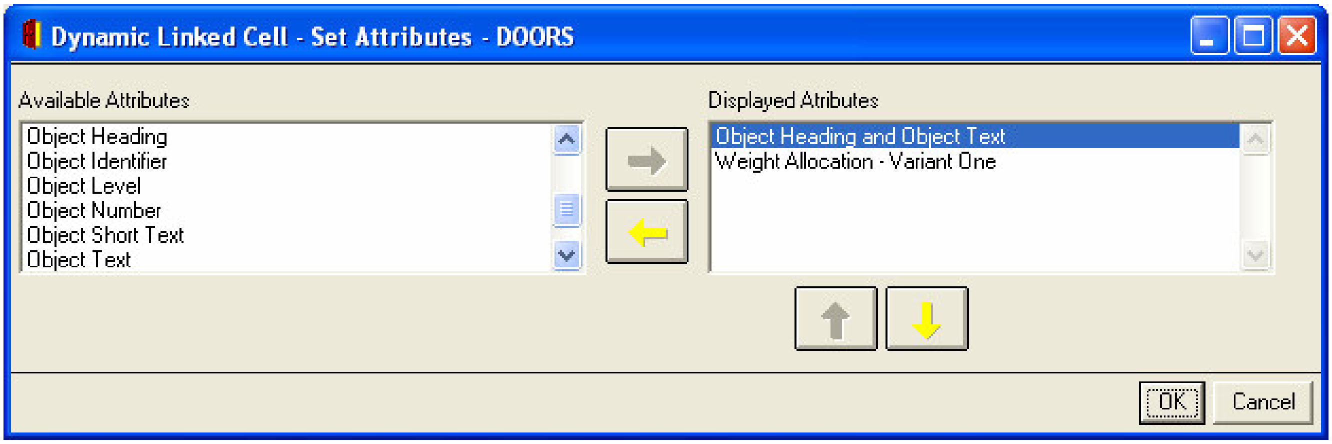


Available Attributes:
- Object Heading
- Object Identifier
- Object Level
- Object Number
- Object Short Text
- Object Text

Displayed Atributes:
- Weight Allocation - Variant One
- Object Heading and Object Text

Figure 23: “Set Dynamic Linked Cell Attributes” – “Object Heading and Object Text” Displayed

When more than one attribute is displayed, individual attributes can be selected and re-ordered to in the list using the up and down arrows.



Available Attributes:

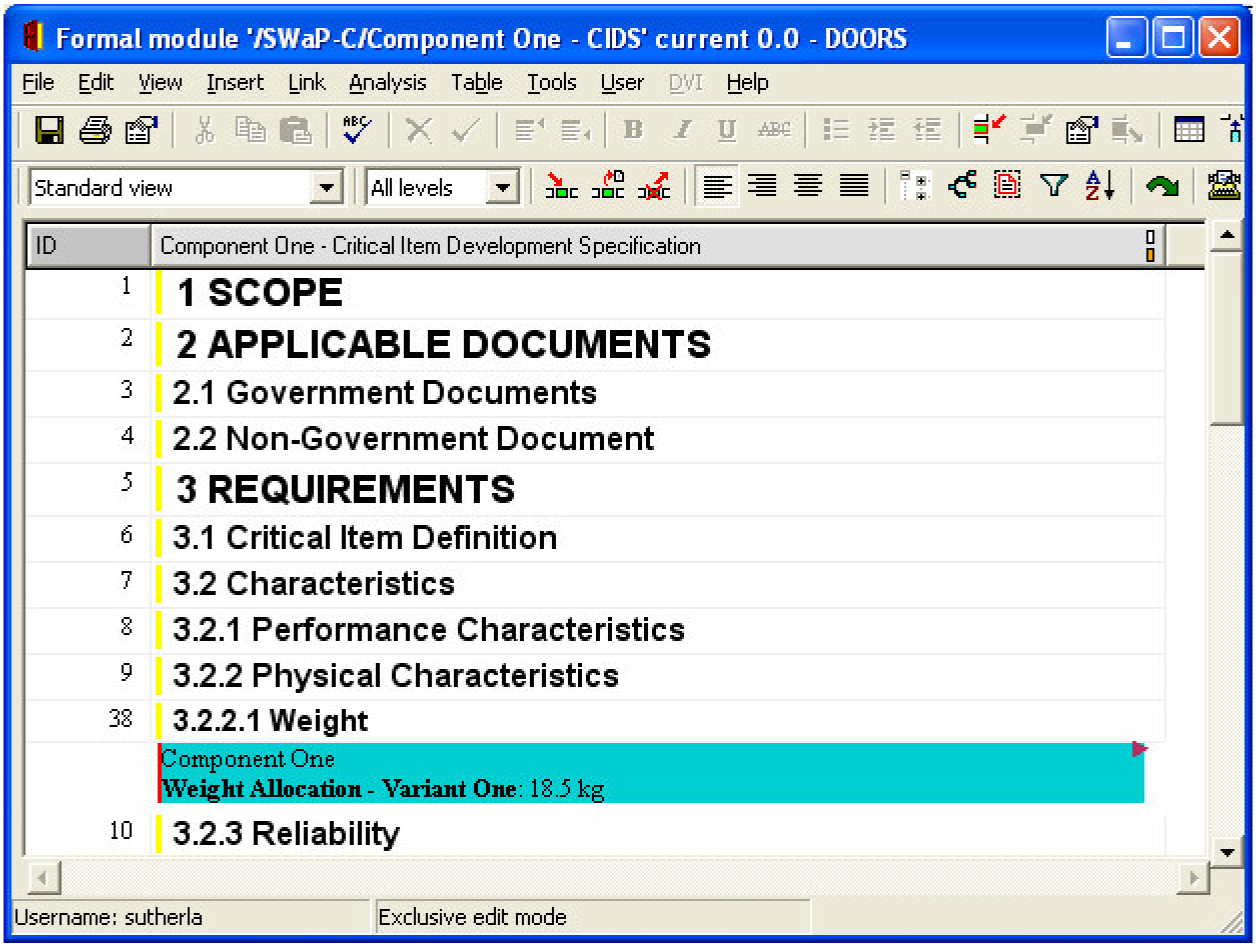
- Object Heading
- Object Identifier
- Object Level
- Object Number
- Object Short Text
- Object Text

Displayed Atributes:

- Object Heading and Object Text
- Weight Allocation - Variant One

Figure 24: “Set Attributes..” – “Object Heading and Object Text” Displayed First

For SWaP-C data, the “Object Heading and Object Text” contains the subsystem or component name. Pairing that with the attribute containing the data for a specific variant gives a complete representation of the data.


Formal module '/SWaP-C/Component One - CIDS' current 0.0 - DOORS
File Edit View Insert Link Analysis Table Tools User DVI Help

Standard view

All levels

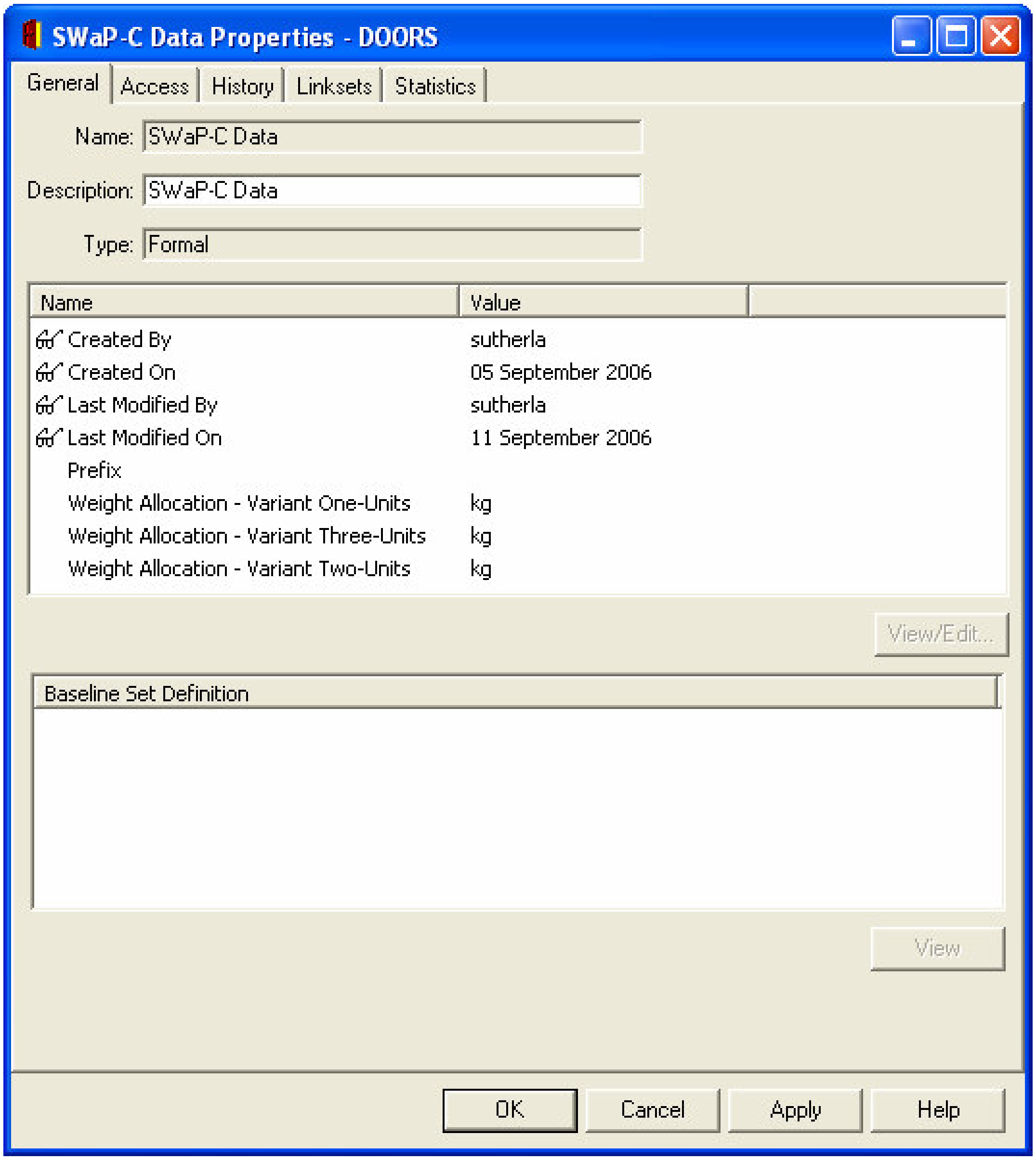
ID	Component One - Critical Item Development Specification
1	1 SCOPE
2	2 APPLICABLE DOCUMENTS
3	2.1 Government Documents
4	2.2 Non-Government Document
5	3 REQUIREMENTS
6	3.1 Critical Item Definition
7	3.2 Characteristics
8	3.2.1 Performance Characteristics
9	3.2.2 Physical Characteristics
38	3.2.2.1 Weight
	Component One **Weight Allocation - Variant One**: 18.5 kg
10	3.2.3 Reliability

Username: sutherla

Exclusive edit mode

Figure 25: “Dynamic Linked Cell” – “Object Heading and Object Text” and one additional attribute displayed

SWaP-C data has units (Weight == kg, Power == Watt, etc.). The SWaP-C module stores these units as Module level attributes, one for each data column. The “Dynamic Linked Cells” use this knowledge to append the units to the data when it is pulled into the module.



Name: SWaP-C Data

Description: SWaP-C Data

Type: Formal

Name	Value
Created By	sutherla
Created On	05 September 2006
Last Modified By	sutherla
Last Modified On	11 September 2006
Prefix	
Weight Allocation - Variant One-Units	kg
Weight Allocation - Variant Three-Units	kg
Weight Allocation - Variant Two-Units	kg

Figure 26: SWaP-C RAM-T Module level “Units” Attributes

Automatic Updates with Attribute DXL:

Since “Dynamic Linked Cells” are implemented with Attribute DXL, they automatically update when a module is opened, or when a user selects “Tools -> Refresh DXL Attributes” in a Module window.

In DOORS v7.x, Attribute DXL refreshes data even if the Module is opened in read-only mode, allowing read-only users to see the latest data. This is desirable when the read-only module being opened is the “current version” of the Module, but is not desirable when the read-only module is a baseline version of a module.

Because of this feature, the “Dynamic Linked Cell” functionality also copies the information contained in the “Cell Text” attribute to the standard “Object Text” attribute. This facilitates the following operations:

- **Baselines:**

  Data in a DOORS baseline should not change, but Attribute DXL is executed in baselined modules, and Attribute DXL cannot be disabled or turned off once the module is baselined.

  To circumvent this problem, the “Dynamic Linked Cells” Attribute DXL code was written to detect if it is being executed in a baseline. In such a case, the Attribute DXL does not update the attribute value. Instead, it displays the value stored in “Object Text”.

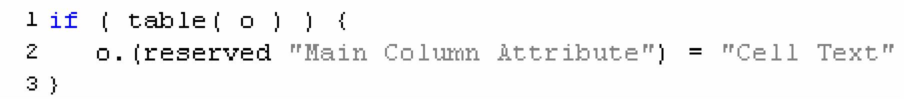
- **Archives:**

  DOORS Archives are used to move entire DOORS modules between databases. Module Archives are for a single module, and do not carry any link information with them. To allow data pulled into a “Dynamic Linked Cell” to be persistent, a DXL script is used to disable the “Cell Text” attribute for “Dynamic Linked Cells”, and the tables are reset to show “Object Text”.

DOORS Table Property: “Value displayed in each table cell”

The DXL used to set the Table Property of the “Value displayed in each table cell” is the undocumented function (reserved “Main Column Attribute”).

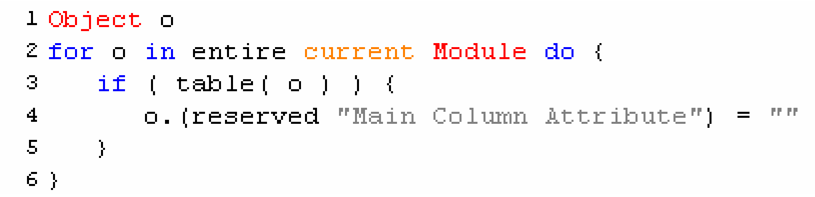
To set the value displayed in the cells of a table to the “Cell Text”, attribute, the following DXL is executed on the Table Header Object:



```
if ( table( o ) ) {
   o.(reserved "Main Column Attribute") = "Cell Text"
}
```

Figure 27: Using DXL to enable “Dynamic Linked Cells”

To set the value to the default of “Object Heading and Object Text”, a null string (“”) value is assigned for all Table Objects.

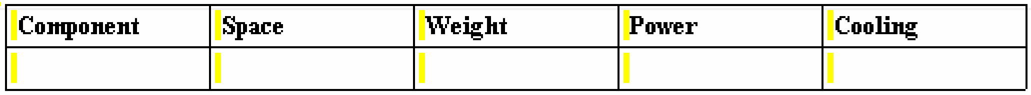


```
Object o
for o in entire current Module do {
   if ( table( o ) ) {
      o.(reserved "Main Column Attribute") = ""
   }
}
```

Figure 28: Using DXL to disable “Dynamic Linked Cells”

DOORS Tables

In the initial implementation of “Dynamic Linked Cells”, the cells were intended to stand alone as a single cell. Since the adoption of “Dynamic Linked Cells”, users have expressed a need to build a larger table comprised of “Dynamic Linked Cells”. This update is being evaluated, and may be implemented if feasible.



Component	Space	Weight	Power	Cooling

Figure 29: Multiple “Dynamic Linked Cells” in a single DOORS Table

“Virtual Objects” in DOORS

The concept of creating self-updating, “virtual objects” in DOORS has been previously conceived and implemented by others (see Appendix A). The main advantages of the “Dynamic Linked Cell” concept are:

- Since Attribute DXL is used, no Triggers are necessary.
- Since Attribute DXL in v7.x shows updated values in read-only mode, users see the latest data in all module open modes.
- The “Set Attribute…” tool allows a user to easily select from the available set of target attributes.
- Referenced attributes appear in the DOORS “main” column, and are exported with the “main” column to Excel or Word “Book” form using the standard DOORS exporters.

Appendix A: Other "Virtual Object" implementations in DOORS:

- Dynamic and Automatic Update of Content Linked from Another Module Using DXL Triggers
    - by John Deely and Nick Nicolai of GE Healthcare Technologies
    - Prepared for the 2005 Telelogic Americas User Group Conference
    - `http://www.telelogic.com/campaigns/2005/americas/ugc/abstracts.cfm?ID=4130&from=wed`
- Comparative Evaluation of Product Line Requirements Architectures
    - Developed at Honeywell by Robert H. Fall, Jennifer Stieglitz, Robert Schlachter, Karen Protola
    - Presented at the 2001 Telelogic Americas User Group Conference
- Virtual Objects? Virtually!
    - by E. M. O'Keefe – Raytheon Company
    - Presented at the 2000 INDOORS Americas User Group Conference

Appendix B: "Dynamic Linked Cells" Download and Installation:

The "Dynamic Linked Cells" software can be downloaded from the following URL:

http://www.galactic-solutions.com/GalacticDownloads.htm

The downloaded .zip file will contain the following files:

- Dynamic Linked Cell\cellText.inc (Attribute DXL)
- Dynamic Linked Cell\Insert\Dynamic_Linked_Cell_Insert_After.dxl
- Dynamic Linked Cell\Insert\Dynamic_Linked_Cell_Insert_Below.dxl
- Dynamic Linked Cell\Insert\Insert.hlp
- Dynamic Linked Cell\Insert\Insert.idx
- Dynamic Linked Cell\Dynamic Linked Cell.hlp
- Dynamic Linked Cell\Dynamic Linked Cell.idx
- Dynamic Linked Cell\Dynamic_Linked_Cell_Set_Attributes.dxl

Extract these files to the "user" directory within the DOORS client installation. The following example location is for a DOORS 7.1 installation:

C:\Program Files\Telelogic\DOORS 7.1\lib\dxl\addins\user