NASA ARM Tool

- The NASA ARM Tool was developed at NASA's Software Assurance Technology Center at Goddard Space Flight Center in Greenbelt, MD.
- This tool conducts an analysis of the test of the SRS document and reports certain metrics.
- The metrics are divided into two categories: micro- and macro-level metrics.

1. Micro-level indicators count the occurrences of specific keyword types.
2. Macro-level indicators are coarse-grained metrics of the SRS documentation.

Micro-level indicators include

- imperatives
- continuances
- directives
- options
- weak phrases

Macro-level indicators include

- size of requirements
- text structure
- specification depth
- readability

Imperatives

The first metric, imperatives, is a micro indicator that counts the words and phrases that command that something must be provided. Imperatives include

- "shall"—dictates the provision of a functional capability
- "must" or "must not"—establish performance requirements or constraints
- "will"—indicates that something will be provided from outside the capability being specified. For example, *"the building's electrical system will power the xyz system."*
- "is required to"—used in specifications statements written in passive voice
- "are applicable"—used to include, by reference, standards or other documentation as an addition to the requirements being specified
- "responsible for"—used as an imperative for systems whose architectures are already defined. For example, *"the xyz function of the abc subsystem is responsible for responding to the pdq inputs."*

- A more precise specification will have a high number of “shall” or “must” imperatives relative to other imperative types.
- Note that the word *“should” is not recommended* for use in an SRS. From both a logical and legal point of view “should” places too much discretion in the hands of system designers.
- The counts of imperatives found in the Smart Home SRS document are shown in Table.

Table 5.3 ARM Counts of Imperatives Found in the Smart Home SRS Document

Imperatives	*Occurrences*
shall	308
must	0
is required to	0
are applicable	0
are to	1
responsible for	0
will	51
should	7
Total	367

- ***Continuances***
- Continuances are phrases that follow an imperative and precede the definition of lower-level requirement specifications.
- Continuances indicate that requirements have been organized and structured.
- These characteristics *contribute to the ease* with which the requirement specification document can be changed.
- *Too many* continuances, however, indicate multiple, complex requirements that may not be adequately reflected in resource and schedule estimates.

Table 5.4 ARM Counts for Continuances in the Smart Home SRS Document

Continuance	*Occurrence*
below	0
as follows	0
following	0
listed	0
in particular	0
support	0
and	85
:	2
Total	87

- ***Directives***
- The micro-indicator “directives” count those words or phrases that indicate that the document contains examples or other illustrative information. Directives point to information that makes the specified requirements more understandable.
- Generally, the higher the number of total directives, the more precisely the requirements are defined.
- ***Options***
- Options are those words that give the developer latitude in satisfying the specifications.
- At the same time, options give less control to the customer.

Table 5.5 Directives Found in the Smart Home SRS

Directive	*Occurrence*
e.g.	0
i.e.	14
For example	0
Figure	0
Table	0
Note	0
Total	14

Table 5.6 Options and Their Counts Found in the Smart Home SRS Document

Option Phrases	*Occurrence*
can	7
may	23
optionally	0
Total	30

- ***Weak Phrases***
- Weak phrases are clauses that are subject to multiple interpretations and uncertainty and therefore can lead to requirements errors.
- Use of phrases such as ***"adequate"*** and ***"as appropriate"*** indicate that what is required is either defined elsewhere or worse, the requirement is open to subjective interpretation.
- Phrases such as "but not limited to" and "as a minimum" provide the basis for expanding requirements that have been identified or adding future requirements.
- The total number of weak phrases is an important metric that indicates the extent to which the specification is ambiguous and incomplete.

- ***Incomplete***
- The “incomplete” micro-indicator counts words that imply that ***something is missing*** in the document, for whatever reason (for example, future expansion, undetermined requirements).
- The most common incomplete notation is “TBD” for “to be determined.”

Variations of “TBD” include

- **TBD—“to be determined”**
- **TBS—“to be scheduled”**
- **TBE—“to be established” or “yet to be estimated”**
- **TBC—“to be computed”**
- **TBR—“to be resolved”**
- “Not defined” and “not determined” explicitly state that a specification statement is incomplete.
- “But not limited to” and “as a minimum” are phrases that permit modifications or additions to the specification.

Table 5.7 Weak Phrases for the Smart Home SRS Document

Weak Phrase	*Occurrence*
adequate	0
as appropriate	0
be able to	3
be capable of	0
capability of	0
capability to	0
effective	0
as required	0
normal	1
provide for	1
timely	0
easy to	1
Total	6

Table 5.8 Incomplete Words and Phrases Found in the Smart Home SRS Document

Incomplete Term	*Occurrence*
TBD	0
TBS	0
TBE	0
TBC	0
TBR	0
not defined	0
not determined	0
but not limited to	0
as a minimum	0
Total	0

- Leaving incompleteness in the SRS document is an ***invitation to disaster*** later in the project.
- While it is likely that there may be a few incomplete terms in a well-written SRS due to pending requirements, the number of such words *should be kept to an absolute minimum*.

- ***Subjects***
- Subjects are a count of **unique combinations of words immediately preceding imperatives** in the source file. This count is an indication of the scope of subjects addressed by the specification.
- The ARM tool counted a total of 372 subjects in the Smart Home SRS document.
- ***Specification Depth***
- Specification depth counts the **number of imperatives at each level** of the document and reflects the structure of the requirements i.e. diamond.

Table 5.9 Numbering and Specification Structure Statistics for Smart Home SRS Document in the Appendix

Numbering Structure		*Specification Structure*	
Depth	*Occurrence*	*Depth*	*Occurrence*
1	19	1	0
2	71	2	50
3	265	3	258
4	65	4	64
5	0	5	0
6	0	6	0
7	0	7	0
8	0	8	0
9	0	9	0
Total	420	**Total**	372

- *Readability Statistics*
- There are various ways to evaluate reading levels, but most techniques use some formulation of characters or syllables per words and words per sentence.
- For example, the ***Flesch Reading Ease index*** is based on the average number of syllables per word and of words per sentence.
- Standard writing tends to fall in the 60–70 range but apparently, a higher score increases readability.
- The Flesch-Kincaid Grade Level index is supposed to reflect a grade-school writing level, so a score of 12, means that someone with a 12th grade education would understand the writing.
- But standard writing averages 7th to 8th grade, and a much higher score is not necessarily good—*higher level writing would be harder to understand*.
- The Flesch-Kincaid Grade level indicator is also based on the average number of syllables per word and on words per sentence. There are other grade level indicators as well (Wilson et al.).

Table 5.10 Sample Statistics from 56 NASA Requirements Specifications (Rosenberg)

	Lines of Text	*Imperatives*	*Continuances*	*Directives*	*Weak Phrases*	*TBD, TBS, TBR*	*Option (can, may…)*
Minimum	143	25	15	0	0	0	0
Median	2265	382	183	21	37	7	27
Average	4772	682	423	49	70	25	63
Max	28459	3896	118	224	4	32	130
Std Dev	759	156	99	12	21	20	39
Level 3 Specs	1011	588	577	10	242	1	5
Level 4 Specs	1432	917	289	9	393	2	2

Flesch Reading Ease index

$$206.835 - 1.015\left(\frac{\text{total words}}{\text{total sentences}}\right) - 84.6\left(\frac{\text{total syllables}}{\text{total words}}\right)$$

The Flesch Reading Ease Readability Formula

The specific mathematical formula is:

RE = 206.835 – (1.015 x ASL) – (84.6 x ASW)

RE = Readability Ease

ASL = Average Sentence Length (i.e., the number of words divided by the number of sentences)

ASW = Average number of syllables per word (i.e., the number of syllables divided by the number of words)

The output, i.e., RE is a number ranging from 0 to 100. The higher the number, the easier the text is to read.

- Scores between 90.0 and 100.0 are considered easily understandable by an average 5th grader.

- Scores between 60.0 and 70.0 are considered easily understood by 8th and 9th graders.

- Scores between 0.0 and 30.0 are considered easily understood by college graduates.

Flesch-Kincaid Grade Level index

$$0.39\left(\frac{\text{total words}}{\text{total sentences}}\right)+11.8\left(\frac{\text{total syllables}}{\text{total words}}\right)-15.59$$

The Flesch-Kincaid Grade Level Readability Formula

Step 1: Calculate the average number of words used per sentence.

Step 2: Calculate the average number of syllables per word.

Step 3: Multiply the average number of words by 0.39 and add it to the average number of syllables per word multiplied by 11.8.

Step 4: Subtract 15.59 from the result.

The specific mathematical formula is:

FKRA = (0.39 x ASL) + (11.8 x ASW) - 15.59

Where,

FKRA = Flesch-Kincaid Reading Age

ASL = Average Sentence Length (i.e., the number of words divided by the number of sentences)

ASW = Average number of Syllable per Word (i.e., the number of syllables divided by the number of words)

Analyzing the results is a simple exercise. For instance, a score of 5.0 indicates a grade-school level; i.e., a score of 9.3 means that a ninth grader would be able to read the document. This score makes it easier for teachers, parents, librarians, and others to judge the readability level of various books and texts for the students.

Theoretically, the lowest grade level score could be -3.4, but since there are no real passages that have every sentence consisting of a one-syllable word, it is a highly improbable result in practice.

Table 5.11 Cross Reference of NASA Indicators to IEEE 830 Qualities (Wilson)

Categories of Quality Indicators	*Indicators of Quality Attributes*										
		Quality Attributes									
	Complete	*Consistent*	*Correct*	*Modifiable*	*Ranked*	*Testable*	*Traceable*	*Unambiguous*	*Understandable*	*Validatable*	*Verifiable*
Imperatives	■			■			■	■	■	■	■
Continuances	■			■	■	■	■	■	■	■	■
Directives	■		■			■		■	■	■	■
Options	■					■		■	■	■	
Weak phrases	■		■			■		■	■	■	■
Size	■					■		■	■	■	■
Text structure	■	■		■	■		■		■		■
Specification depth	■	■		■			■		■		■
Readability				■		■	■	■	■	■	■