A Primer on Argument

version 2.0

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The purpose of this document is to provide a common understanding of terms, concepts, principles, and uses of argument. It emphasizes the practical over the theoretical and the simple over the complicated.

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1 Preliminaries

Humans have been studying argument for a long time, for several millennia in fact before anyone conceived of "safety cases" or "assurance cases." The literature on the subject is deep and wide and growing (see for example [2] & [8]). Nothing we present here is new in any fundamental sense. We are not trying with this document to contribute to the general philosophical or legal literature of argument, nor to the specific literature of the assurance case community. Rather, we are synthesizing and (we hope) simplifying the ideas that are directly applicable to constructing and assessing arguments within the safety-critical systems domain.

Readers who are familiar with work in safety and assurance cases over the last couple of decades will notice some differences here[1]. Most of these differences are rooted in our emphasis on harmony with the mature principles of argument over harmony with the adolescent ideas of assurance cases. None of the differences should be interpreted as us saying the other stuff is necessarily erroneous[2]. We are only establishing *one* common understanding suitable for anchoring the use of argument.

The document is organized as follows. Section 2 identifies and defines the primitives (*aka* terms) necessary to speak and reason coherently about arguments. Section 3 presents precepts we believe should be kept clearly in mind as any application of argument to safety critical systems proceeds. Section 4 notes several practical matters that arise, and begins their consideration. Section 5 wraps everything up. Throughout, to distinguish between explanatory text and the things you need to remember forever,

> we narrow the margins around the "you must remember this" [4] material, and collect it all in Appendix A.

2 Primitives

In this section, we are going against type. Rather than providing the OED-like, lexicographically precise definitions we relish, we will stick to the rather informal-ish (but nevertheless adequately precise) language Michael developed a while back for reasons initially unrelated to safety-critical systems or even to his NASA job in any way.

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[1] Even from some previous papers and presentations we ourselves have given. Michael is in the process of revising his *Understanding Assurance Cases* [3] to comply more closely with the ideas presented in this document.

[2] There *is* a bunch of erroneous stuff out there, but not all of it is, and we're not trying to separate the chaff from the wheat in this document.

Although we make full use of colors as an aid to identifying and distinguishing among specific defined terms, the colors have no meaning, and are not necessary. SMALL CAPS also identify the defined terms. All terms not explicitly defined are assumed to have a meaning consistent with their use in ordinary English, and which can be unambiguously determined from the context.

2.1 ARGUMENT, BELIEVE, CONCLUSION

We begin, as you probably suspected we would, with ARGUMENT[3]:

> An ARGUMENT is an attempt to convince others to BELIEVE a CONCLUSION through REASONING and one or more PREMISES.

In general, an ARGUMENT may be oral or written, but for safety-critical system purposes we will be concerned almost exclusively with written ARGUMENTS[4]. An ARGUMENT may also be ATOMIC or compound. We'll explain the distinction shortly, but let's first consider BELIEVE, CONCLUSION, PREMISE, and REASONING in that order.

The basic word 'believe' is one of those frequently used words for which nearly everyone believes they have a correct understanding, but which has many subtly (and some not so subtly) different senses, some of which are mutually contradictory. Philosophers have been known to have battles over 'believe' at least as intense as the battles engineers have over probabilities of failure. As fascinating as these battles are, using ARGUMENT within engineering disciplines does not require participating in them, or even picking sides. For our purposes, we can rest content with this very simple definition:

> To BELIEVE is to accept as true.

But, someone may ask, "What is truth?" To which we reply, paraphrasing Justice Potter Stewart, "You know it when you see it." [6] Within the context of arguments about whether an engineered artifact possesses the desired properties, the existential question of the meaning of truth will never arise. The questions will always be about *whether* a specific statement is sufficiently BELIEVABLE (or not) within the specific context in which it appears. Whether it is abstractly or universally true will not matter.

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[3] Michael is compelled to insert this footnote identifying the corresponding relevant sense (#4) of the term as given in the OED [1]: "A connected series of statements or reasons intended to establish a position (and, hence, to refute the opposite) …"

[4] For our purposes, *written* encompasses arguments that are recorded, e.g. via analog or digital documentation, and expressed using text, graphical, tabular, or other representations. All such representations are *notational variants* for expressing and elaborating the primitives described herein.

One particular type of statement about which these questions will arise is the CONCLUSION of an ARGUMENT, because

> The CONCLUSION is the statement you want your audience to BELIEVE.

2.2 PREMISE, REASONING

To convince your audience, you will make use of things you think they *already* BELIEVE. Calling each of those things by the term first recorded in written English in 1398 [5], we say

> A PREMISE is a statement you think your audience BELIEVES.

Many traditional explanations of argumentation stop here, separating an ARGUMENT into only two parts: CONCLUSION and PREMISES. Most explanations of assurance cases do not use the word PREMISE at all. We think both of these approaches are less clear than they ought to be.

A simple bifurcation is less clear than it needs to be because it leaves to the audience the task of either figuring out *why* the given PREMISES are adequate to justify the CONCLUSION, or deciding *which* of the specific PREMISES explains why the others provide sufficient justification. We free the audience from this burdensome and risky task by requiring an explicit statement in the ARGUMENT.

> Your REASONING states why you think the PREMISES should cause your audience to BELIEVE your CONCLUSION.

A PREMISE-free explanation is also problematic because it falsely suggests that an assurance case is something different in kind from a traditional ARGUMENT. Recognizing, however, that some of the assurance case community's alternate terms may have some value to some people in some situations, we adapt appropriate definitions for two of those common terms:

> EVIDENCE is the name you *may* give to a PREMISE you're certain your audience BELIEVES.[5]

> ASSUMPTION is the name you *may* give to a PREMISE you are *not* prepared to justify if your audience does not BELIEVE it.

Neither EVIDENCE nor ASSUMPTIONS are anything more (or less) than PREMISES. Whether the terms are used is a matter of style not of substance.

We have now explained all of the primitives that constitute an ARGUMENT: CONCLUSION, REASONING, PREMISE(S), and BELIEVE. A CONCLUSION alone is not an ARGUMENT. REASONING alone is not an ARGUMENT. A PREMISE or several PREMISES is not an ARGUMENT. Several PREMISES and some REASONING do not an ARGUMENT make. And even a CONCLUSION with

[5] The use of the term 'evidence' is highly problematic. We reluctantly use it here because of its current ubiquity and put off until another day a serious attempt to address the problems.

REASONING and one or more PREMISES is not an ARGUMENT, unless it is being offered for the purpose of trying to convince someone to BELIEVE the CONCLUSION.

2.3 BINDING, DEFEATER

As much as the reader may wish we were, we are not quite done. There are two more primitives and three helpful terms we need to introduce. First, the additional primitives.

Sometimes understanding an ARGUMENT requires more information than can be conveniently expressed in the CONCLUSION, REASONING, or PREMISES. We borrow a term from programming language theory to use BINDING as the primitive for information of this form.

> A BINDING is an association between a term used in an ARGUMENT and the real-world information to which that term refers.

One example of a BINDING is a definition, through which the meaning of a particular word or phrase in the ARGUMENT is constrained. Any engineering-related ARGUMENT will almost certainly include BINDINGS corresponding to one or more of the definitions from the relevant technical disciplines. Other examples of BINDINGS are references to external documents or other artifacts in which relevant information is contained.

One more primitive to go. It is called a DEFEATER.

> A DEFEATER is a statement that may cause your audience to *not* BELIEVE your conclusion.

Whereas a PREMISE provides support for BELIEVING the CONCLUSION, a DEFEATER provides support for *not* BELIEVING it Or, at least for not believing that the given ARGUMENT compels BELIEF[6].

2.4 ATOMIC, COMPOUND, COGENT

That's it for the primitives, but we further introduce two *almost*-primitives to facilitate unambiguous conversations by providing a way to distinguish between ARGUMENTS with one level of depth and those with multiple levels:

> An ATOMIC ARGUMENT consists of a single CONCLUSION together with its immediate REASONING, PREMISES, BINDINGS (if present), and DEFEATERS (if present).

> A COMPOUND ARGUMENT is an ARGUMENT consisting of more than one ATOMIC ARGUMENT.

[6] Within the philosophical literature, distinguishing between two or sometimes more types of defeaters is common. We do not think those distinctions are necessary or even helpful for engineering arguments, and follow the approach (but not the language; he uses 'rebuttal') of Toulmin [8].

Finally, we introduce an adjective to describe good ARGUMENTS.

> An ARGUMENT is called COGENT if it rationally justifies BELIEVING its CONCLUSION to the required standard of confidence.

Consider, for example, the legal system of the United States. The required standard of confidence for a judge or jury to convict a criminal defendant is (with some slight variations in wording depending on the state) "beyond a reasonable doubt." In contrast, to find for the plaintiff in a civil action, the judge or jury need only reach a "more likely than not" standard of confidence. An ARGUMENT that is COGENT for a civil action may well not be COGENT in a criminal trial.

A complete listing of all terms and definitions described in this section is given in Appendix A. With a clear, sufficient vocabulary established and explained, we move on to enumerating precepts for guiding the development and assessment of arguments for use within the safety-critical systems domain[7].

3 Precepts

Through study and experience, we have collected a number of observations that, turned into guiding principles, support a consistent theory and practice of ARGUMENT development and assessment. We will refer to these collectively as the Precepts and introduce them here.

3.1 LOCALITY

We have differentiated between ATOMIC and COMPOUND ARGUMENTS above because these structural levels have relevance in ARGUMENT construction and assessment, Specifically, the PREMISES of one ATOMIC ARGUMENT, if requiring further rationale for their believability, themselves become CONCLUSIONS of supporting ARGUMENTS. Linked together in chains or hierarchies, these ATOMIC ARGUMENTS comprise an integrated COMPOUND ARGUMENT. However, while a CONCLUSION of any complexity requires a COMPOUND ARGUMENT to organize its rationale, each CONCLUSION at the atomic levels must be worthy of BELIEF for the CONCLUSION of the COMPOUND ARGUMENT to also be worthy of BELIEF.

> The precept of LOCALITY reminds us that *COMPOUND ARGUMENTS are always assessed one ATOMIC ARGUMENT at a time.*

Applying this precept[8] to figuring out how best to assess an ARGUMENT tells us we can (well, really *must*) focus assessment at the ATOMIC ARGUMENT level. That is, when assessing whether

[7] Although the intended audience for this paper are engineers (both researchers and practitioners) of safety-critical systems, almost everything presented here is applicable to just about any other audience, too.

[8] The name of the precept originated in Michael's mantra, "All arguments are local." He coined the statement long ago based on the saying, "All politics is local," which was used most famously by (but was not original

BELIEVING a particular CONCLUSION is justified, we assume its PREMISES are true, and consider only whether their truth and the stated REASONING, in the context created by any **bindings** and DEFEATERS, provides the necessary justification. We do not look elsewhere within the ARGUMENT**.** To assess a COMPOUND ARGUMENT, one assesses iteratively each ATOMIC ARGUMENT contained therein.

3.2 DEPTH

Since a premise of one ATOMIC ARGUMENT can become a CONCLUSION of a supporting ARGUMENT, we can infer that ARGUMENTS may in theory descend *ad infinitum*. In practice, we obviously don't do this. In order to be of genuine practical use, ARGUMENT decomposition must descend far enough to serve stakeholder objectives, and not so far as to unnecessarily consume resources, create distraction, or put into an ARGUMENT something that is better expressed in some other form. It was easy to write that; it is harder to do, and we'll return to this in forthcoming discussions. Nonetheless,

> The precept of DEPTH reminds us to *descend no deeper than necessary*.

3.3 CERTAINTY

As it was more straightforward to *describe* a target depth of decomposition than to *find* it, it is similarly more straightforward to describe a target level of precision or certainty in documenting ARGUMENT components than it is to accomplish it. Since the ARGUMENTS with which we are concerned are *informal*[9], we are searching not for a property of mathematical precision in specifying ARGUMENT elements, but rather for one of *pragmatic sufficiency*. That is, in stating PREMISE(S), CONCLUSION, REASONING, or other component of an ARGUMENT, we recognize that we can never achieve absolute formality of precision or certainty**.** However, we target with mindful attention a level that is pragmatically sufficient to the purposes at hand. As with DEPTH, we will revisit operational guidance for such decisions during our ensuing group work.

> The precept of CERTAINTY reminds us that *certainty is certainly not possible*.

3.4 CHANGE

Any ARGUMENT of the type with which we are concerned is constructed in the context of a real-world state, including the respective states of entities over which it argues, as well as the respective states of knowledge and understanding of those contributing to its documentation.

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to) former Speaker of the U.S. House of Representatives (1977-1987) Tip O'Neill. We originally stated the precept in Michael's original words, but have revised it as shown here to be consistent with the more recent COMPOUND / ATOMIC distinction**.**

[9] See the precept of INDUCTION for more on informality.

Even ARGUMENTS considered some form of "final" for system lifecycle purposes are still subject to change, for example, in light of post-deployment experience. Importantly, ARGUMENTS themselves have lifecycles, and go through stages of development with implications that (1) must be attended to, and (2) can be leveraged. That is, irrespective of process codification including configuration management, change management, and other conventions of complex development processes, we recognize that any discrete snapshot of an argument represents a point in a continuously changing space described by a large number of informal variables. We discretize this space to some degree in order to manage development processes, for systems *and* for arguments. But what an argument says, and to what it applies, is under refinement throughout its development, and subject to change even afterward should new need or knowledge arise.

> The precept of CHANGE reminds us that *ARGUMENTS are living structures*.

3.5 INDUCTION

Related closely to the precept of CHANGE is the precept of INDUCTION. In stating that even a "final" ARGUMENT is subject to update, we have implied that new PREMISES can affect BELIEF in a CONCLUSION. This is true for the ARGUMENTS with which we are concerned and differentiates these from another type. The study of argument differentiates CONCLUSIONS that can be *proven* through the application of formal logic to sufficient PREMISES (deductive ARGUMENTS), and those that are in contrast *BELIEVABLE* through the application of any other type of reasoning (inductive ARGUMENTS)[10]. All ARGUMENTS with which we are concerned refer to real-world state that cannot be formalized.

> The precept of INDUCTION reminds us that *the ARGUMENTS with which we will concern ourselves are uniformly*[11] *inductive ARGUMENTS*.

3.6 PLAUSIBILITY

In an ideal world, everyone would assess in the same way whether a particular ARGUMENT (even an inductive one) is COGENT. Even without the possibility of certainty, consensus about COGENCY seems both desirable and feasible (well, at least a consensus among those with sufficient subject-area and argumentation knowledge). In the real world, agreement does not always happen.

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[10] We are simplifying things a little bit here, as modern philosophers of logic often speak of additional categories or sub-categories such as analogical, explanatory, and defeasible arguments. Most of the arguments likely to be used in engineering applications would properly fit into the defeasible category. We shall not speak of this again.

[11] Note a compound inductive argument might include occasional nested deductive arguments, which does not change the fact that at the relevant level of abstraction, it is still an inductive argument.

Many different theories have been proposed over the centuries to explain why equally qualified people sometimes assess differently the COGENCY of an ARGUMENT. These theories may be combined and summarized as follows: The propositions a person BELIEVES (whether explicitly or subconsciously) *before* evaluating an ARGUMENT establish in advance the boundaries within which that person will judge the COGENCY of the ARGUMENT. Or in fewer words:

> The precept of PLAUSIBILITY reminds us that *presuppositions predetermine plausibility*.

If, for example, Teresa and Joyce (both smart and knowledgeable people) assess the COGENCY of an ARGUMENT differently, their different assessment may have nothing to do with the ARGUMENT itself. Rather the differences may rest in conflicting opinions about the truth of matters that are (necessarily) implicit in the ARGUMENT**.**

3.7 EFFICACY

Although ARGUMENTS are subjectively cool and objectively useful for prompting thinking about why a particular CONCLUSION is BELIEVABLE, not everything needs to, or should, be expressed as an ARGUMENT. Rarely will a CONCLUSION that is part of the accepted body of knowledge within a discipline need to be justified by ARGUMENT. If it needs to be justified at all within a particular application, the already accepted approaches should usually be sufficient. Or, in precept form:

> The precept of EFFICACY reminds us that *you need* ARGUMENT *only when you need* ARGUMENT.

If something other than ARGUMENT (for example, mathematical formulas or empirical experiments) are good enough, then nothing more needs to be provided.

These seven precepts — LOCALITY, DEPTH, CERTAINTY, CHANGE, INDUCTION, PLAUSIBILITY**,** and EFFICACY — should be kept continually in mind wherever ARGUMENT is used.

4 Practicalities

The material so far has laid down a consistent and elegant intellectual foundation for applying ARGUMENT to safety-critical systems matters. This section addresses some practical issues that are sure to arise.

4.1 Concerning adding to primitives and precepts

The primitives and precepts presented here establish a core working lexicon and set of relationships to anchor and unify the more complex discussions, constructions, and assessments

that will be needed in any industrial application. As the objectives within a particular application grow more advanced, consideration of additional concepts, meaning distinctions, and options for representation may arise. Making additions is fine, but users should resist the tendency to multiply primitives or precepts unnecessarily, and should carefully document any additions they make.

4.2 Concerning notations

When the time comes to document working ARGUMENTS, choosing one or more representations becomes necessary. As described earlier, all analog and digital records of ARGUMENTS captured via text, graphical, tabular, or other data, are *notational variants* of each other and more importantly of the primitives.

Further, any notation has the power to facilitate or impede expression and reception of the primitives, and conventional use of some familiar notations in the community has muddied this water. When a representation is chosen, its alignment with the primitives should be documented, and, if necessary, constraints on use and interpretation of the notation imposed in order to maintain integrity of the primitives. To be precise:

> For any notation chosen, its language should be modified to the extent needed to conform to the primitives defined in this document.

4.3 Concerning speaking about assurance cases

The phrase "assurance case" (or "safety case") is common within the safety-critical systems community, at least in some locations. Our experience and observations have suggested the phrase (or any of its close variants) tends to complicate rather than facilitate conversations about the fundamental ideas. The reasons for the complications vary. Some people seem unable to think of assurance cases as anything other than big diagrams in (usually) the Goal-Structuring Notation (GSN); they often entirely miss the centrality of ARGUMENT. Some people, particularly those of a certain mathematical bent, seem to think the only legitimate goal for assurance cases is to embody formal, deductive ARGUMENTS exclusively. Some other people, mostly computer scientists or engineers, think exclusively in terms of tool support, including tools to (purportedly) quantify confidence.

But the most essential reason we have concentrated on ARGUMENT and not cases is because it is in creating and assessing the ARGUMENTS that the need for guidelines and examples is most acute. Arranging ARGUMENTS as part of a collection of documents is not the hard part. Creating pragmatically sufficient ARGUMENTS and assessing their COGENCY are the hard parts.

Creating pragmatically sufficient ARGUMENTS and ensuring they are COGENT are the hard parts.

5 Prognosis

This document has established a common set of terms, concepts, and principles to guide the use of argument within safety-critical systems development and assurance. We do not claim that our set is necessarily the only possible one, but we believe it is one worth pursuing vigorously.

With apologies to the great J. R. R. Tolkien[12] we close with an admonition. Go back? No good at all! Go sideways? Impossible! Go forward? Only thing to do! Let us go on with our hearts all of a patter and a pitter.

[12] See [7] (or any other edition) for the original words.

6 Precedents

[1] "argument, n." OED Online, Oxford University Press, March 2020, www.oed.com/view/Entry/10663. Accessed 31 March 2020.

[2] Govier, Trudy. 2010. *A Practical Study of Argument*. 7th edition. Belmont, CA: Cengage Learning.

[3] Holloway, C. Michael. 2018. *Understanding Assurance Cases: An Educational Series in Five Parts*. https://shemesh.larc.nasa.gov/arg/uac.html

[4] Hupfeld, Herman. 1931. "As Time Goes By." Made famous by Dooley Wilson as Sam in Warner, Jack L., *et al.* 1942. *Casablanca*. Warner Bros. Pictures, Inc., 1942.

[5] "premise, n." OED Online, Oxford University Press, March 2020, www.oed.com/view/Entry/150302. Accessed 9 April 2020.

[6] Stewart, Justice Potter. *Jacobellis v. Ohio*. 378 US 184, 197, 1963.

[7] Tolkien, J.R.R. *The Hobbit.* Houghton Mifflin Harcourt. Kindle Edition. p. 69.

[8] Toulmin, Stephen E. 2003 (1958). *The Uses of Argument*. Cambridge, UK: Cambridge University Press.

[9] Holloway, C. Michael. 2019. *Understanding the Overarching Properties.* NASA/TM-2019-220292. https://ntrs.nasa.gov/citations/20190029284

Appendix A - "you must remember this"

An ARGUMENT is an attempt to convince others to BELIEVE a CONCLUSION through REASONING and one or more PREMISES.

To BELIEVE is to accept as true.

The CONCLUSION is the statement you want your audience to BELIEVE**.**

A PREMISE is a statement you think your audience BELIEVES.

Your REASONING states why you think the PREMISES should cause your audience to BELIEVE your CONCLUSION.

EVIDENCE is the name you *may* give to a PREMISE you're certain your audience BELIEVES.

ASSUMPTION is the name you *may* give to a PREMISE you are not prepared to justify if your audience does not BELIEVE it.

A BINDING is an association between a term used in an ARGUMENT and the real-world information to which that term refers.

A DEFEATER is a statement that may cause your audience to *not* BELIEVE your CONCLUSION.

An ATOMIC ARGUMENT consists of a single CONCLUSION together with its immediate REASONING, PREMISES, BINDINGS (if present), and DEFEATERS (if present).

A COMPOUND ARGUMENT is an ARGUMENT consisting of more than one ATOMIC ARGUMENT**.**

An ARGUMENT is called COGENT if it rationally justifies BELIEVING its CONCLUSION to the required standard of confidence.

The precept of LOCALITY reminds us that *COMPOUND ARGUMENTS are always assessed one ATOMIC ARGUMENT at a time.*

The precept of DEPTH reminds us to *descend no deeper than necessary*.

The precept of CERTAINTY reminds us that *certainty is certainly not possible*.

The precept of CHANGE reminds us that *ARGUMENTS are living structures*.

The precept of INDUCTION reminds us that *the ARGUMENTS with which we will concern ourselves are uniformly inductive ARGUMENTS.*

The precept of PLAUSIBILITY reminds us that *presuppositions predetermine plausibility*.

The precept of EFFICACY *reminds us that you need ARGUMENT only when you need ARGUMENT.*

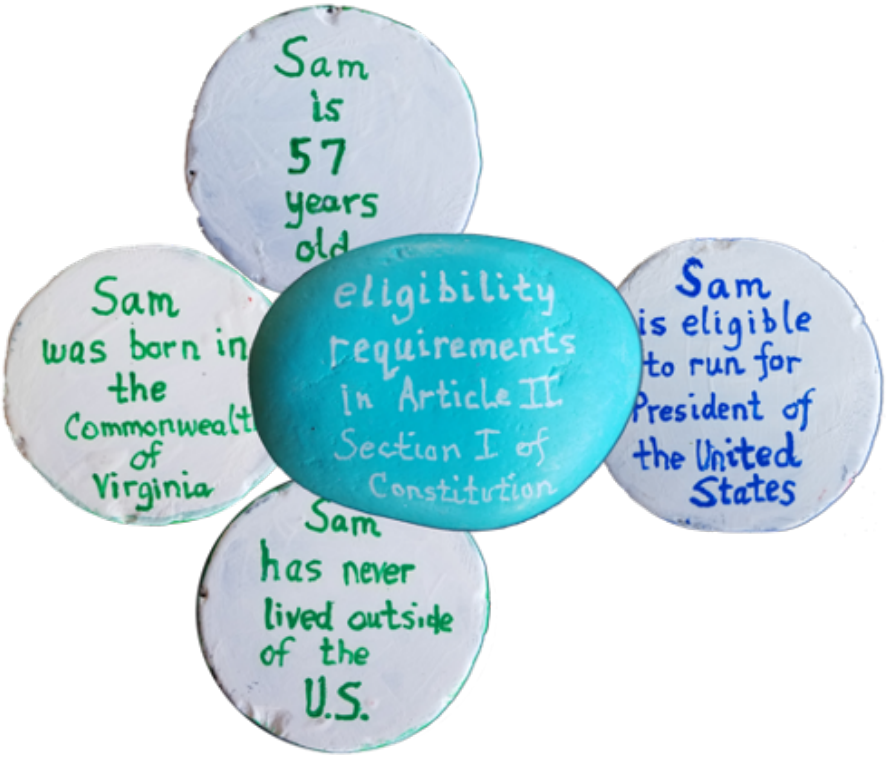
For any notation chosen, its language should be modified to the extent needed to conform to the primitives defined in this document.

Creating pragmatically sufficient ARGUMENTS and ensuring they are COGENT are the hard parts.

Appendix B - Example Arguments

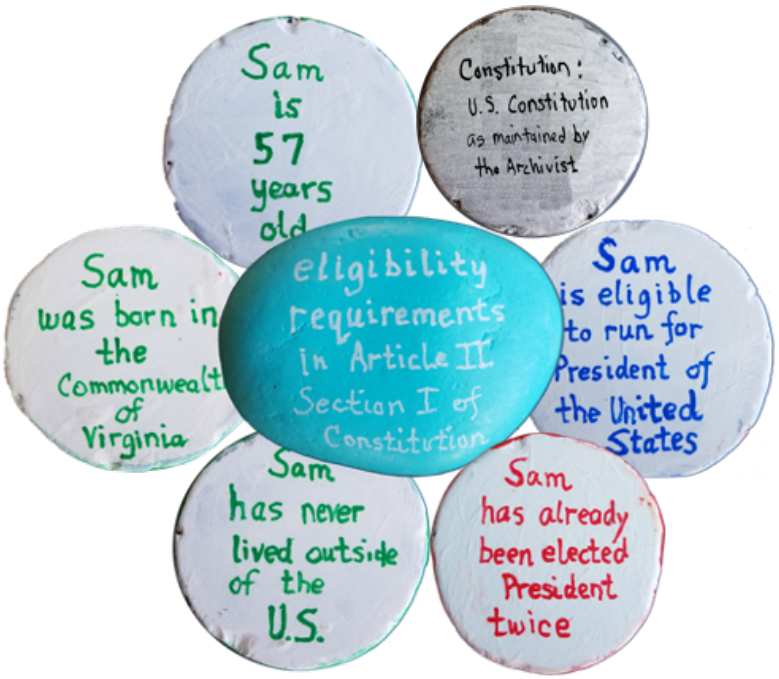
Here is a series of simple examples illustrating the meaning of the primitives explained in Section 2. We present the examples in a notation (painted rocks) we believe is self-explanatory but also clearly not a notation anyone will use in practice, and on a subject no one will think is biased towards hardware or software.

Example 1: an ATOMIC ARGUMENT

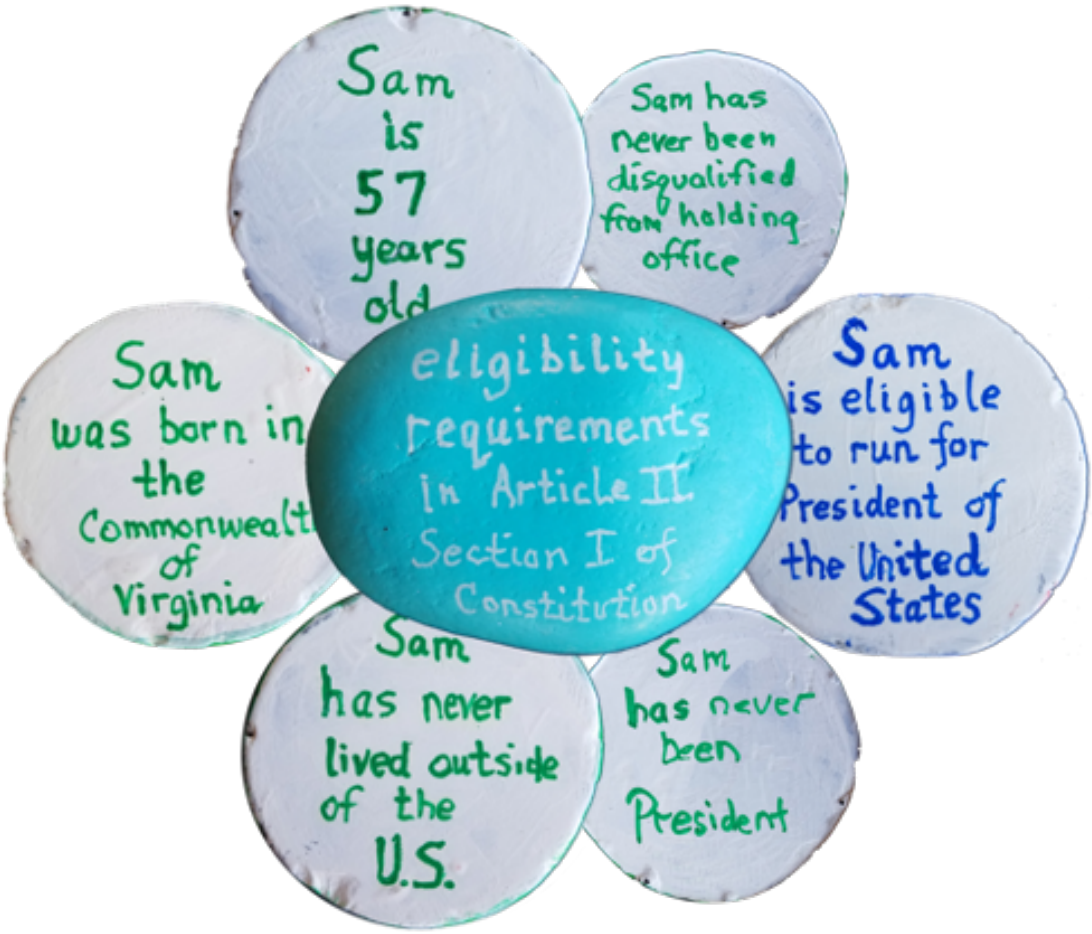


Example 2: an ATOMIC ARGUMENT with a BINDING

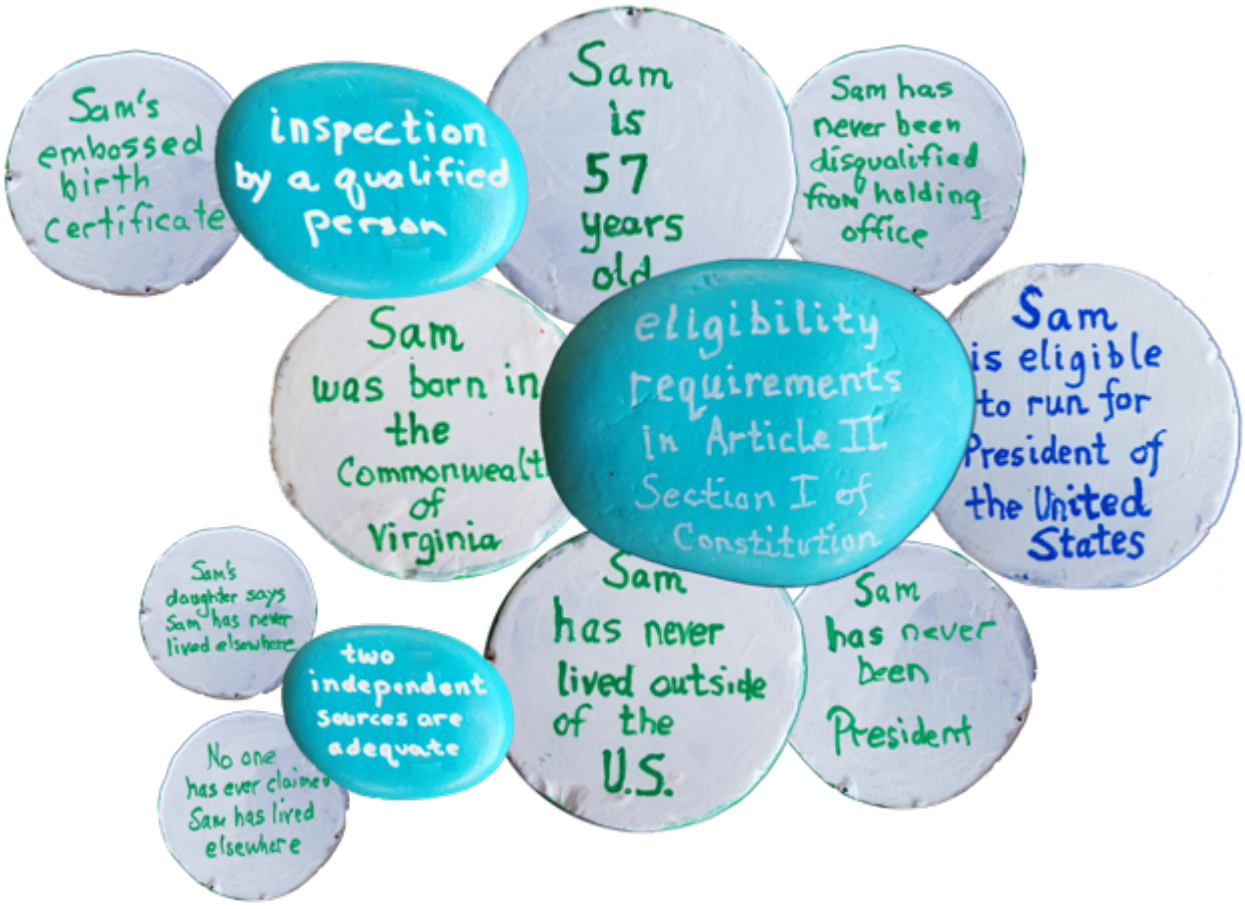
Example 3: an ATOMIC ARGUMENT with a **binding** and a DEFEATER



Example 4: an ATOMIC ARGUMENT modified to eliminate the DEFEATER

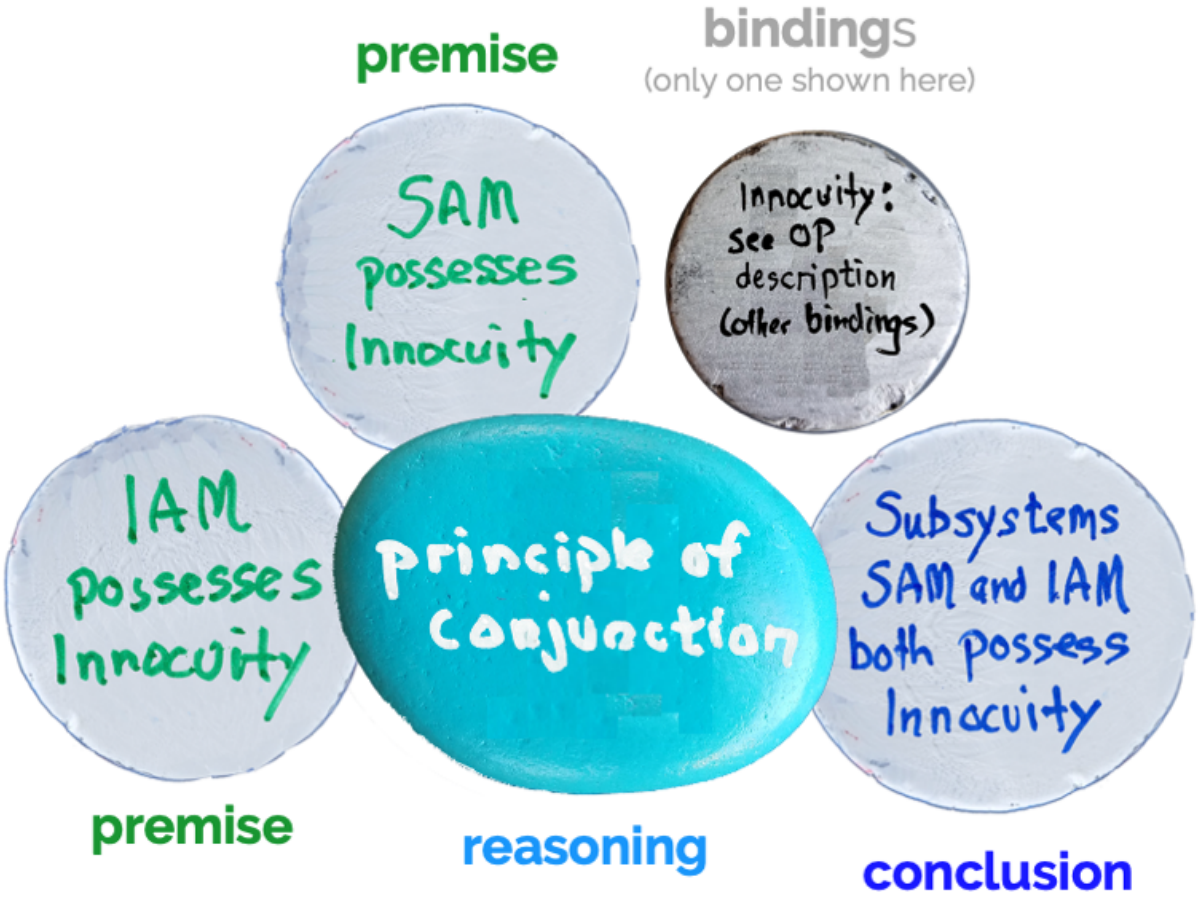


Example 5: a COMPOUND ARGUMENT

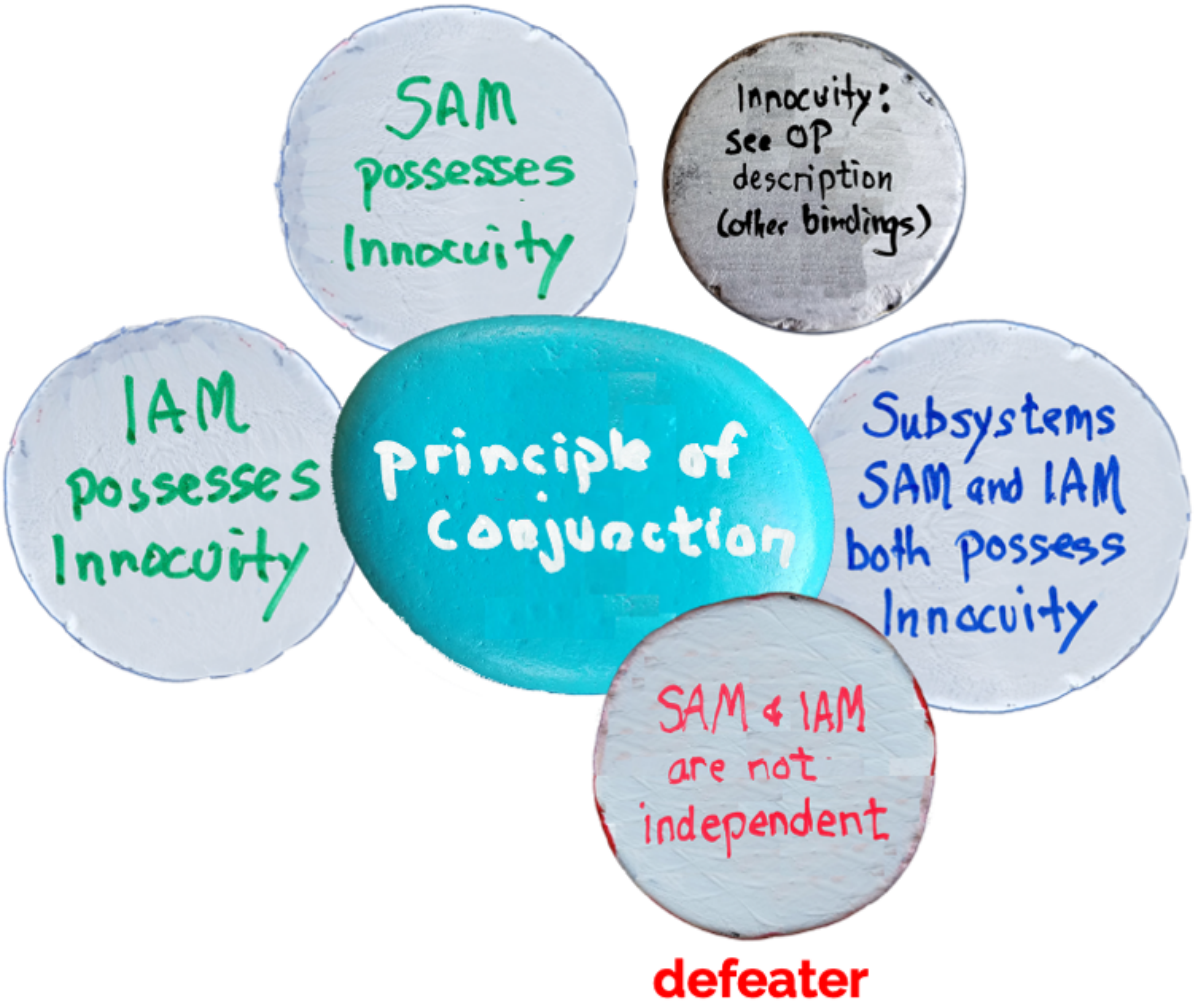


We now present some examples from a written-in-stone (albeit quite incomplete) ARGUMENT concerning the Overarching Properties [9].

Example 6: an initial ATOMIC ARGUMENT

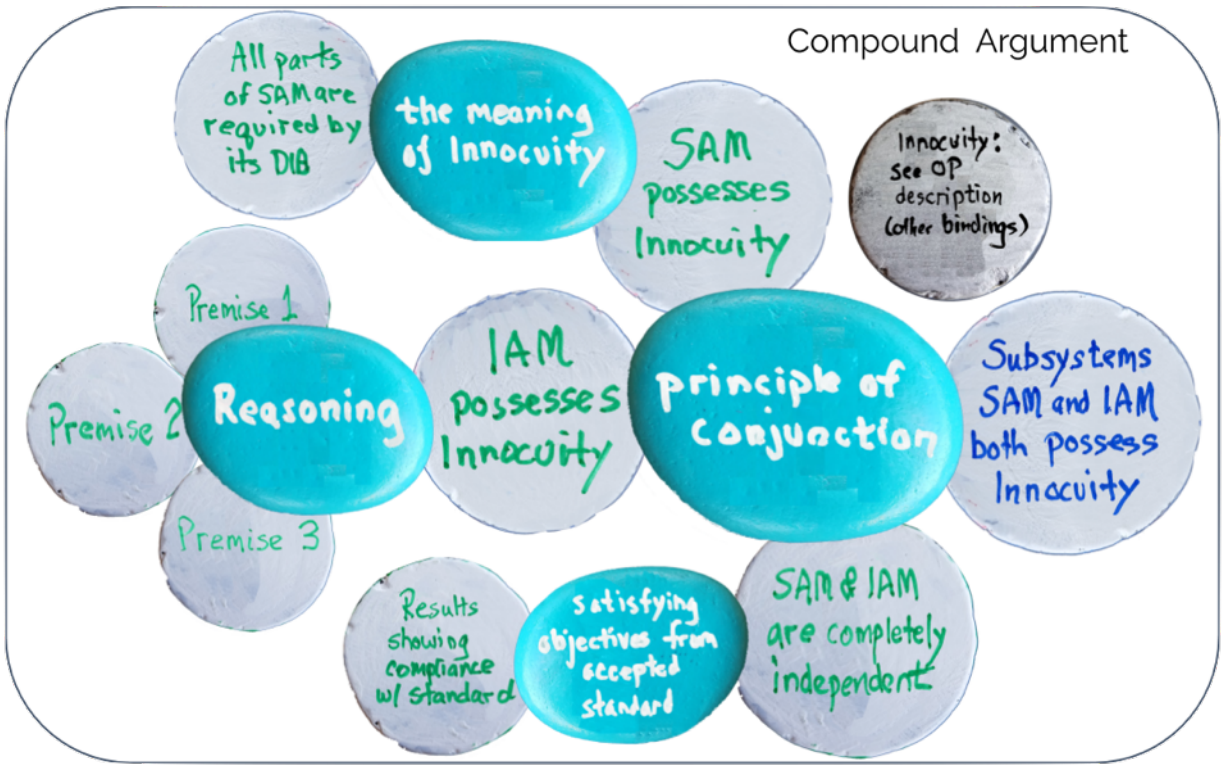


Example 7: a DEFEATER discovered



Example 8: the DEFEATER defeated

Example 9: the **ARGUMENT** expanded



Example 10: the four constituent ATOMIC ARGUMENTS