A FORMAL LANGUAGE FOR DESCRIBING EFFECTS (VDL)

Will Harvey, Ph.D.
Finale Fireworks
165 Hawthorne Ave
Palo Alto, California 94301 USA
will@finalefireworks.com

*** (EARLY) INTERNAL DRAFT FOR FEEDBACK ***

ABSTRACT

Effect names of firework products generally provide a brief description of the effect sufficient for identifying the product in an inventory or pick list. There are times, however, when a more precise description of the effect is required. For these cases, such as describing an effect with sufficient precision to have it manufactured or to create a visual simulation, it is helpful to have an Interlingua for describing effects that is easily readable, unambiguous, and expressive enough to define effects at whatever level of particularity is required, from a general description of a shell such as “Peony” or “Willow” to a precise recipe of the fuse delays and effect types that go into the design of a cake.

This paper presents a visual description language called VDL that has these properties. The paper begins with a short tutorial for writing effect descriptions in VDL, then presents a formal definition of the language expressed as a context-free grammar, and then goes on to discuss applications of the language ranging from the obvious applications in circumstances requiring precise communication to more esoteric applications such as defining a set of visual effect identifiers to enumerate and uniquely identify a large class of visual effects.

The large class of visual effects stops short of an attempt to standardize a language for all effect names, for such an ambition carries the weight of ruling out anything that is not contemplated in the language or that is expressed in other terms that a manufacturer or designer may prefer. The language of VDL does not have to be universal to be useful. One out of a thousand effects may not even be describable in VDL, but for the other nine hundred and ninety-nine VDL can provide a variety of practical communication benefits.
INTRODUCTION

Most pyrotechnics professionals and hobbyists familiar with the art can look at a firework effect name and easily interpret what it means based on an understanding of the terms and the grammatical structure of the phrase. While the interpretation may seem easy, neither the understanding of the terms nor the grammatical structure is actually obvious. For example, the effect name “Silver Brocade” describes an effect with a stringy silver trail of sparks, but the effect name “Red Brocade” describes an effect with a stringy trail of sparks and a red flame. To the layperson, the words “Silver” and “Red” are just colors. To the pyrotechnic practitioner they have additional semantics based on a deeper understanding of how some colors apply to a star’s trail of sparks and others apply to its flame envelope.

Grammatical structure is even less obvious. The effect name “Red Chrys To Blue With Crackle” has at least eight plausible interpretations, all different:

1. Red Chrys To Blue Chrys With Crackle Core (trail continuing through transition)
2. Red Chrys To Blue Star With Crackle Core (trail ending on transition)
3. Red Chrys To Crackling Blue Chrys
4. Red Chrys To Crackling Blue Star
5. Crackling Red Chrys To Crackling Blue Chrys
6. Crackling Red Chrys To Crackling Blue Star
7. Red And Blue Chrys With Crackle Core (two colors of stars, no transition)
8. Crackling Red And Blue Chrys (two colors of stars, no transition)

Even pyrotechnic practitioners have difficulty disambiguating the meaning of the name, since the grammatical structure allows for crackle to apply to either or both color stages of the star (or as a separate core), and since the transition description “Red Chrys To Blue” is silent on what happens to the trail as the flame color changes from red to blue. Does the Chrysanthemum style trail of sparks continue through the transition or end when the flame changes to blue? Further ambiguity arises in translation from other languages to English, such as with the use of “To” for combinations as in the example of writing the combination of red and blue stars as “Red To Blue.”

In spite of these ambiguities, though, effect names work perfectly adequately for purposes of identifying product. Even to someone unfamiliar with the product, these brief descriptions

\[\text{\footnotesize\textsuperscript{1}}\text{Beyond even the complexity of the semantics and ambiguity of the grammar, effect names often incorporate new terms that don’t have established meaning beyond a single manufacturer, such as Vulcan’s “Cosmic Rain Peony.”}\]
provide just enough information to identify a product in an inventory or pick list. In essence, effect names are what they are: names.

There are times, though, when a name is not enough. If a display company is purchasing product from a distributor, the display company would understandably like to specify the product being purchased with precision at least at the level of disambiguating the eight possible interpretations above because those differences could matter in the design of a show. Additional examples can be found in all areas of the industry. If a wholesaler is designing a shell or cake to be manufactured by a different company, it is obviously useful to be able to speak about the design with particularity so the two parties can agree on what is to be manufactured. If an operator is importing a pack list into a computer choreography program for visual simulation, the operator needs unambiguous interpretations of the effect descriptions to get an accurate visual simulation of the show. In all of these examples and in many other situations, what is called for is a visual effect description language that is precise and unambiguous. This paper proposes such a language, “VDL,” and presents a formal description of the language grammar and its semantics.

**VDL – A VISUAL DESCRIPTION LANGUAGE**

Before launching into a discussion of language properties, though, it is worth mentioning that the VDL language proposed in this paper is not a departure from the effect names used today. Indeed effect names like “Red Peony” and “Crackling Silver Chrys With Red Tail” are examples of VDL already. VDL simply formalizes the grammar and the interpretation of effect names so as to eliminate the types of ambiguity illustrated by the eight interpretations of a single effect name above.

The next section walks through the process of describing shells, comets, and mines in VDL. This short tutorial serves as a natural starting point for introducing the language, as it is easier to discuss the properties of the language and its formal grammar later on once the language is familiar.

**DESCRIBING EFFECTS IN VDL**

**Shells**

A shell description follows a basic pattern of describing the flower first, followed by a sequence of star transitions expressed as “To” phrases, followed by a sequence of additions expressed as “With” phrases, followed by an optional tail specification also expressed as a “With” phrase ending in the word “Tail.”
Illustrating the grammar, the simplest shell description is just a single word flower description, such as “Peony.” Flower descriptions can be more than one word, combining adjectives and nouns that describe the properties of the break and the initial properties of the stars. For example, the following are all valid flower descriptions,

- *Peony*
- *Red Peony*
- *Red Crackling Chrys*
- *Red Crackling Chrys Ring*
- *Titanium Salute*

In a flower description, all the words function as adjectives except the last, which functions as a noun. Some pyrotechnics terms can function as either an adjective or a noun, depending on the context. The word “Chrys” above serves as a noun in the third effect name, describing the star trails and the shape of the flower, and serves as an adjective in the fourth effect name, describing just the star trails. The flower type “Salute” is a special type of flower that cannot be followed by any transitions or “With” phrases since it does not break into stars.

In this grammatical structure, phrases that include star transitions are not themselves valid flower descriptions. Thus the phrase “Red To Blue Peony” is not a valid flower description because it incorporates the word “To.” Instead, the correct way to represent such an effect in VDL is “Red Peony To Blue.” The phrase “Red Peony” is the flower description, and the phrase “To Blue” is the star transition.²

Like flower descriptions, the star transitions can also include multiple words that describe the properties of the stars (though not the break). All the words must function as adjectives except the last, which can be a terminal effect such as “Crackle” or “Report”. The following are both valid, but different, shell descriptions:

- *Blue Peony To Red Chrys To Crackle*
- *Blue Peony To Red Chrys To Crackling*

The first describes a Peony shaped shell whose stars transition from blue flames to red flames with Chrysanthemum trails to a burst of crackling sparks. The second describes a similar shell whose stars transition from blue flames to red flames with Chrysanthemum trails to just *crackling* trails.

² Star transitions are of the form, “To <StarDesc>” or “To <Terminal>,” where <StarDesc> contains only adjectives describing the star, and <Terminal> contains adjectives followed by a noun that describes the end of the star’s life, such as “Crackle” or “Report.”
In VDL, star transitions are always interpreted following the rule that the description before the “To” does not continue through the transition unless it is repeated after the “To.” Thus if you want to describe a red Chrysanthemum flower that transitions to blue stars with no trails, you can just write “Red Chrys To Blue,” but if you want trails after the transition also, you need to write “Red Chrys To Blue Chrys.” The rule applies to star flames the same way as it applies to star trails. If you want to describe a red Peony flower that transitions to stars with trails and no flame, write “Red Peony To Chrys,” but if you want the red flame after the transition also, you need to write “Red Peony To Red Chrys.”

Shells that contain pistils or cores or an outside ring can be described using “With” phrases that begin with the word “With” and end with a word describing the shape, such as “Core” or “Pistils” or “Ring.” The body of a “With” phrase follows similar grammatical structures to the shell itself, beginning with a star description, continuing optionally with star transitions, and finishing with the word that describes the shape, such as “With Red To White To Blue Pistils.” The following are all valid shell descriptions using “With” phrases:

- Peony With Chrys Pistils
- Peony With Crackle Core
- Peony With Red To Blue To Strobing Ring

Since all “With” phrases end with words like “Pistils” or “Core,” it is incorrect to try to indicate a report using a “With” phrase, as in “Peony With Chrys Pistils With Report.” Since the report is actually a terminal transition of the pistil stars themselves, the correct description is, “Peony With Chrys To Report Pistils.”

The last phrase in a shell description can specify the tail using a grammar that is nearly identical to the grammar of the “With” phrases. The phrase “Peony With Tail” is the

3 VDL follows the interpretation rule that descriptions before the “To” do not continue through the transition unless they are repeated because it is a simple rule to remember and can apply unambiguously for all types of effects, including transitions in mine particles and comets. Some effect names in use today with transitions before the flower description, such as “Red To Blue Chrys,” support a preferred interpretation that the flower description to the right of the “To” applies both before and after the “To” (i.e., that such a phrase is equivalent to “Red Chrys To Blue Chrys”). While this preferred interpretation would seem to violate the rule, the ambiguity is not present in VDL because in VDL the flower name always precedes the transitions.

4 “With” phrases are of the form “With <StarDesc> <To> <To> <To>...<Shape>” where the <To> phrases are star transitions, as defined earlier, and the <StarDesc> is a sequence of adjectives describing the star. The <StarDesc> differs from a <Flower> in that a <Flower> ends in a noun that describes the flower shape, whereas as <StarDesc> describes only the stars and is silent on the shape. Some flower terms like “Chrys” can be used either as a noun to describe the flower shape and the stars, or as an adjective to describe just the stars themselves; other flower terms like “Peony” are rarely used as adjectives, and therefore are only found in <Flower> phrases, not in <StarDesc> phrases.

5 The “Tail With” phrases are of the form “With <TailDesc> <To> <To> <To>...Tail” where the <TailDesc> is a sequence of adjectives like the <StarDesc> and the <To> phrases are tail transitions. Some adjectives that imply a physical package that attaches to a shell, such as Tiger Tail, are possible only in <TailDesc> and tail transitions. Tail transitions cannot include terminal effects.
simplest tail phrase. The phrase “Peony With Red To Blue Tail” is a more complicated example. Unlike “With” phrases, tail phrases cannot end in a terminal effect. The name “Peony With Red To Crackle Tail” is invalid because “Crackle” is a terminal effect implying a final burst of sparks, though the phrase “Peony With Red To Crackling Tail” is valid because “Crackling” is a property of the tail that does not imply its termination. It is also correct in VDL to write “Peony With Rising Tail” though the word “Rising” is not required.

Sometimes shells that contain comet-like stars with thick trails are called comet shells so VDL accommodates comet shells and Crossette-comet shells in the flower descriptions exactly as is commonly written, with the word “Shell” at the end of the flower description unless the flower description already ends in a flower pattern or shape term such as “Ring” as in these examples:

- Comet Shell
- Xette Comet Shell
- Xette Comet Ring
- Xette Comet Ring To Crackling

Without the word “Shell” or “Ring,” these shell descriptions could be confused with comet devices, which are discussed next.

**Comets**

Comet descriptions are similar to shell descriptions, except simpler because comets do not have a break. The grammatical pattern for comets is simply an optional initial comet description followed by a sequence of comet transitions, followed by the word “Comet”:

\[
\text{<CometDesc> <To> <To> <To>… Comet}^6
\]

The simplest example of a comet description is just, “Comet.” The initial comet description in the pattern above can include adjectives that describe properties of the comet, though obviously not words that entail a break. The initial comet description is in fact grammatically identical to the star descriptions defined earlier, and the comet transitions are identical to the star transitions defined earlier. The following are some example complete comet descriptions without transitions:

- Comet

---

6 There is one exception to this grammar, for crossette comets, which is discussed below in the section covering crossettes.
Xette Comet
Red Star Comet
Gold Wave Comet

Since the comet transitions are identical in grammatical structure to the star transitions, the following are all valid complete comet descriptions that include transitions:

Gold To Red Star Comet
White Star To Red Comet
Gold Wave To Report Comet
White Star To Red To Blue Comet

Some effect names in use today include transitions after the word “Comet,” as in “Comet To Red Star.” In VDL the transitions all occur before the word “Comet,” as that appears to be more common usage, so you would have to write the “Comet To Red Star” description as “Gold To Red Star Comet,” introducing the word “Gold” or some other applicable initial comet description adjective to go before the transition.

Since a comet’s description begins at launch instead of at a break, comets obviously don’t need a separate tail phrase. And since comets don’t have breaks, there is no need to specify pistils or a core. The grammar for comets is thus simpler than shells, requiring no “With” phrases whatsoever.

The word “Comet” can also be used to describe a type of star in a shell, similar to a Palm shell, as in the shell name “Comet Shell To Crackle.” If the effect description includes a phrase beginning with “Comet” and ending in “Shell,” then the phrase is a flower description and the effect description is a shell. If the effect description includes the word “Comet” without “Shell” then the phrase is an initial comet description and the effect description is a comet. Actual comet descriptions are easy to recognize because they always end in the word “Comet.”

Mines

Mines can incorporate bouquets of multiple types of particles in addition to bombettes or stars that are lifted with the same charge, so the grammar for mines is slightly more complex than the grammar for shells and comets. It starts with an optional primary mine description phrase and set of particle transition phrases that are identical in grammatical structure to the initial comet description phrase and its transitions.

\(<\text{MineDesc}\> <\text{To}> <\text{To}> <\text{To}>\ldots \text{ Mine } <\text{With}> <\text{With}> <\text{With}>\ldots <\text{Incl}> <\text{Incl}> <\text{Incl}>\ldots\)
Thus some of the simplest mine descriptions look a lot like the comet descriptions with the word “Mine” instead of “Comet”:

Mine
Red Star Mine
Red To Blue Mine
Gold Wave To Report Mine
White Star To Red To Blue Mine

The difference in interpretation, obviously, is that mines eject multiple particles by this description, whereas a comet is a single projectile. To accommodate additional types of particles in the mine, the mine description can include multiple “With” phrases following a grammatical structure identical to the “With” phrases in shell descriptions except with the ending word “Stars” or “Comets” instead “Pistils,” “Core” or “Ring.”

Some examples of mine descriptions incorporating multiple types of particles are,

Red Mine With Comets
Red Mine With Blue Stars
Chrys Mine With Red To White Stars
Chrys Mine With Red To Crackle Stars
Chrys Mine With Red To Crackling Stars

As described in the shell section earlier, the words “Crackle” and “Crackling” in the third and fourth effect descriptions above have different meanings, with the “Crackle” stars ending in bursts of sparks and the “Crackling” stars transitioning to stars with a crackling trail.

If the mine includes flowering bombettes they can be incorporated into the effect description following the word “Including,” with one phrase per type of included bombette. The bombette description after the word “Including” follows the same grammatical structure and semantics as the shell description above, and thus provides the same expressiveness, including the ability to specify the tails. The following verbose mine description illustrates all components of the grammar:

Chrys To Red Star Mine With White To Blue Stars With White To Red Stars Including White Peony With Tiger Tail

Mines and shells can also incorporate comets, subshells, and inserts in complex arrangements in their grammatical structure, as illustrated by these examples:

Comet Mine
Chrys Dragon Eggs Ring
Farfalla Ring With Red Pistils

There is one exception to this grammar for mine “With” phrases that include Crossette comets. This exception is covered below in the section on Crossettes.
Glittering Gold Xette To Purple Star To Report

The first description “Comet Mine” is obviously a mine of comet-like projectiles. The second effect description “Chrys Dragon Eggs Ring” is a shell with a ring shaped pattern of Dragon Eggs subshells. The word “Chrys” describes the trail of sparks behind the Dragon Eggs subshells before they break into clusters of sparks. The third effect description similarly describes a canister shell with Farfalla inserts breaking into a ring with red stars in the center. Finally, the fourth description is of an Escudo Crossette Shell in which the Crossette inserts transition from an initial glittering gold stage lasting up until their split to a purple star stage following the split and ultimately ending in report.

Crossettes

As a type of star or insert, Crossettes can be used in a shell or mine or launched as a comet, so phrases describing Crossettes are actually incorporated into the grammars discussed in the sections above. In the simple cases, Crossettes are incorporated in a shell’s flower description or as an adjective in a comet’s initial comet description or a mine’s primary mine description, as in these examples:

Red Xette (shell)

Xette Comet (comet)

Xette Mine (mine)

The simplicity of the language hides the differences in the three examples. A Crossette shell or mine is a device that contains Crossette stars or inserts, whereas a Crossette comet is the Crossette projectile itself. The semantic difference helps explain a difference in grammatical structure that appears when dealing with transitions.

For shells, the word Crossette is part of the flower description, so if you want to describe transitions of the Crossettes you do so with “To” phrases that follow the word Crossette, as in:

Red Xette To Blue (shell)

Red Chrys Xette To Blue Chrys To White Chrys (shell)

Xette Comet Shell To Glittering (shell)

The adjectives before the word “Xette” describe the stage of the Crossette prior to its split. The “To” phrases after the word “Xette” describe the stages after the split. The first example represents a Crossette that changes color from red to blue when it splits. The second represents a Crossette that changes from red to blue when it splits, and that later on changes to white, leaving a trail on all three stages. If the Crossette is a comet-type projectile that splits, it is written in the flower description as “Xette Comet” as in “Xette Comet Shell To Glittering.” As mentioned above, the word “Comet” requires adding “Shell” to distinguish “Xette Comet Shell” from just “Xette Comet,” which is obviously a comet, not a shell.

Crossettes and Crossette comets can also be included in shells as pistils, as in “Peony With Xette Pistils” or “Peony With Xette Comet Pistils.”
For comets, transitions are written before the word “Comet” as in “Red To Blue Comet” (see previous section). However, to keep Crossette comets consistent for all device types, Crossette comets follow an exception to the standard comet grammar. They are written “<XetteComet> <To> <To> <To>…” with the transitions after the initial Crossette comet description. Some examples are,

- Xette Comet To Glittering (comet, not a shell)
- Red Xette Comet To Blue (comet, not a shell)

For mines, the word Crossettes is part of the primary mine description at the beginning of the phrase, as in “Xette Mine” or “Red Xette Mine” or “Comet Xette Mine.” If the Crossette undergoes transitions, they are written after the primary mine description, as in “Red Xette Mine To Blue.” This pattern is consistent with the grammar for mines described above. There is an exception, however, for Crossette comets in mine “With” phrases. Since the “With” phrases for comets already end in the word “Comets,” the “To” phrases for Crossette comets in “With” phrases come between the word “Xette” and “Comets,” as in “Red Mine With White Xette To Blue Comets.” This is the only circumstance in which the words “Xette” and “Comets” can be separated, and it is so unlikely it is barely worth mentioning. Crossettes included in mine bombettes, though equally unlikely in reality, follow the same grammar as for shells, mentioned here only for sake of completeness.

**Cakes, Candles, Ground Effects, Rockets, and Others**

*(TBD: these sections not written yet.)*

**INTERPRETING EFFECT DESCRIPTIONS UNAMBIGUOUSLY**

The three goals of VDL are to be easily readable, unambiguous, and expressive. The previous sections have addressed the first goal by way of describing the language itself. This section addresses the second.

*(TBD: this important, foundational section is not written yet. It must differentiate between incomplete and ambiguous, and define an interpretation for the vocabulary of the language and a default table for filling in incomplete descriptions with predictable default properties. It also needs to include semantic constraints of the language for eliminating contradictory adjective combinations, etc.)*

**NONSENSICAL DESCRIPTIONS**

It is probably clear from some of the earlier examples that you can describe visual effects in VDL that are not possible to implement as pyrotechnic devices. While it might be nice to have a language that can only describe physically implementable effects, this “tightness”
property is not a goal of the VDL language. Attempting to design a “tight” language risks failing to be “expressive” (able describe all effects that are physically implementable), which is a far more important property. Expressiveness is discussed in the next section.

EXPRESSIVENESS

The last of VDL’s three goals is expressiveness, or its ability to describe all pyrotechnic devices. Natural languages such as English all have the property of being universally expressive – they can describe anything. However it would be hopelessly difficult to define a natural language formally in terms of its grammar or semantics, so natural languages are not viable candidates as effect description languages. However, we can consider them as examples of expressive languages.

Unfortunately, by comparison with natural languages it is obvious that VDL is actually not universally expressive, in spite of the fact that expressiveness is one of the goals of the language. There are obviously colors, types of trails, differences in break properties, and any number of arbitrarily fine distinctions of visual effects that are not describable in the vocabulary and grammar of VDL.

While it may be possible to define a formal language that is universally expressive, VDL satisfies a less ambitious goal – to describe effects at the level of particularity that is actually useful in practice, from a general description of a shell such as “Peony” or “Willow” to a recipe of the fuse delays and effect types that go into the design of a cake. As additional colors or effects are discovered or invented, or as increased levels of detail become desired, the language can be extended to accommodate. The vocabulary and grammar described in this paper can be thought of as a framework for a working language that evolves as the requirements of the art change over time.

UNIQUENESS

(TBD: this property not figured out yet. Is it possible to define VDL such that every visual effect describable in VDL has exactly one description? If so, then effect descriptions in VDL can be converted to numbers that can serve as unique identifiers of all visual effects; if not, then descriptions can still be converted to number identifiers, they just may not be unique (multiple identifiers could identify the same effect). Uniqueness would allow you to compare two number identifiers for equality as a way of testing if the visual effects they describe are the same. I don’t yet have a sense for how important this property is, or how difficult it would be to achieve.)

VDL GRAMMAR
The walkthrough of the language in the earlier section stands on its own as a tutorial, providing enough guidance to a pyrotechnic practitioner or someone familiar with the art to understand any VDL effect description that he reads. However, the walkthrough is not rigorous enough to define the language. One of the goals for the language is that everyone can reach exactly the same understanding of the language rules, not just generally. For this, the computer science study of languages and compilers provides the necessary tools.

Most computer programming languages fall in a class of languages whose basic syntax can be formally defined using a context free grammar. While VDL is not principally a programming language, it is a member of this class of languages, which enables VDL to be described succinctly with the grammar below, expressed in Backus-Naur Form.

Formal grammars such as this are notoriously difficult to read, even for people trained in compiler technologies. It is not important for the pyrotechnic practitioner to understand this grammar. It is important, though, that the grammar exists, as it provides the definitive specification of the language syntax. Computer programmers can create parsers that recognize the language defined by this grammar, and in so doing can write programs that interpret VDL effect descriptions of inventory files, that match effect descriptions to visual simulations, that make visual simulations from effect descriptions, that translate between different human languages, and that connect pyrotechnics software made by different providers.

The VDL grammar below is a computationally practical type of context free grammar called an LALR(1) grammar, which means that computer programmers familiar with compiler generation can create a compiler for this language easily by entering this grammar as input to a compiler generator such as YACC.  

\begin{verbatim}
Effect → Shell | Mine |
  Mine → Mine including Shell | Bouquet |
  Bouquet → Bouquet with More | Particles .
Particles → Red ParticlesMod | Particles1 |
  ParticlesMod → Red ParticlesMod | Particles1Mod .
  Particles1Mod → Pearl Particles3Mod | Particles3Mod .
  Particles3Mod → Chrys Particles3Mod | Xette mine ToOption |
    DragonEggs mine |
    FlyingFish mine |
    Comet mine ToOption |
  mine ToOption .
Particles1 → Pearl Particles3Mod | Particles3 |
  Particles3 → Chrys Particles3Mod |
\end{verbatim}

\begin{verbatim}
WithOption → with WithCont |
  .
  WithCont → Peony ToOption Pistils WithOption |
    Xette RingOption ToOption Pistils WithOption |
    DragonEggs RingOption Pistils WithOption |
    FlyingFish RingOption Pistils WithOption |
    Farfalla RingOption Pistils WithOption |
    Ring ToOption Pistils WithOption |
    LoudOption Crackle Pistils WithOption |
    Pistils WithOption |
    tail |
    Red RedCont |
    Pearl PearlCont |
    Chrys ChrysCont |
    Comet CometCont .
RedCont → Peony ToOption Pistils WithOption |
  Xette RingOption ToOption Pistils WithOption |
  DragonEggs RingOption Pistils WithOption |
  FlyingFish RingOption Pistils WithOption |
  Ring ToOption Pistils WithOption |
  Pistils WithOption |
  to ToTailPistils |
    tail |
    Red RedCont |
\end{verbatim}

\footnote{Electronic copy of the VDL grammar is freely available at: \url{www.finalefireworks.com/features/papers}.}
| Xette mine ToOption | DragonEggs mine | FlyingFish mine | Farfalla mine | Comet mine ToOption |
| mine ToOption. |
| Shell → Flower | LoudOption Salute TailOption. |
| Flower → Red FlowerMod |
| Flower1. |
| FlowerMod → Red FlowerMod |
| Flower1Mod. |
| Flower1Mod → Pearl Flower3Mod |
| Flower3Mod. |
| Flower3Mod → Chrys Flower3Mod |
| Chrys ToOption WithOption |
| Xette RingOption ToOption WithOption |
| Comet ToOption |
| Comet RingOption shell ToOption WithOption |
| FlyingFish RingOption WithOption |
| DragonEggs RingOption WithOption |
| Ring ToOption WithOption |
| Peony ToOption WithOption |
| Flower1 → Pearl Flower3Mod |
| Flower3. |
| Flower3 → Chrys Flower3Mod |
| Chrys ToOption WithOption |
| Xette RingOption ToOption WithOption |
| Comet ToOption |
| Comet RingOption shell ToOption WithOption |
| DragonEggs RingOption shell ToOption WithOption |
| FlyingFish RingOption WithOption |
| Ring ToOption WithOption |
| Peony ToOption WithOption. |
| More → Red MoreMod |
| Red ToOption |
| More2. |
| More2 → Pearl More4Mod |
| Pearl ToOption |
| More3. |
| More3 → Chrys More4Mod |
| Chrys ToOption |
| Xette ToOption |
| DragonEggs |
| FlyingFish |
| Farfalla |
| Comet. |
| More4Mod → Chrys More4Mod |
| Chrys ToOption |
| Xette ToOption |
| DragonEggs |
| FlyingFish |
| Comet. |
| MoreMod → Red MoreMod |
| Red ToOption |
| More2Mod. |
| More2Mod → Pearl More4Mod |
| Pearl ToOption |
| More3Mod. |
| More3Mod → Chrys More4Mod |
| Chrys ToOption |
| Xette ToOption |
| DragonEggs |
| FlyingFish |
| Comet. |
| TailOption → with WithTail |
| . |
| WithTail → tail |
REFERENCES


(2) Hanson, Garry. Precocious Pyrotechnics. Personal communication. October 2010.