<u>Semantic Design</u>

The following is what I call a 'semantic design' for Nu's scripting system (as well as an unrelated replacement for micro-services called MetaFunctions). The concept of a semantic design is inspired by Conal Elliot's denotational design - https://www.youtube.com/watch?v=bmKYiUOEo2A.

To specify semantic designs generally, I've created a meta-language called SEDELA (for <u>Se</u>mantic <u>De</u>sign <u>La</u>nguage). First, we present the definition of SEDELA, then the semantic design for Nu's scripting system as well MetaFunctions in terms of SEDELA. Although I may aim to write a parser and type-checker for SEDELA, there will never be a compiler or intepreter. Thus, SEDELA will have no syntax for **if** expressions and the like. The only Meanings (SEDELA's nomenclature for functions) defined in the Prelude will be combinators such as id, const, flip, and etc. SEDELA's primitive types are all defined in terms of Axioms (types without formal definitions) with no available operations.

Sedela Language Definition

Axiom :=	Axiom**[!]** "Informal definition."	*where ! denotes intended effectfulness*
Meaning Type :=	A -> ... -> Z	*where* A ... Z *are* **Type Expressions**
Meaning Defn :=	f (a : A) ... (z : Z) : R = **Expression | Axiom**	*where* f *is the* **Meaning Identifier** *and* a ... z *are* **Parameter Identifiers** *and* A ... Z, R *are* **Type Expressions**
Expression :=	**Example:** f a (g b)	*where* f *and* g *are a* **Meaning Identifiers** *and* a *and* b *are* **Paremeter Identifiers**
Product :=	MyProduct<...> = A **|** (***A*** : A, ..., ***Z*** : Z) **| Axiom**	*where* MyProduct<...> *is the* **Product Identifier** *and* ***A*** ... ***Z*** *are* **Field Identifiers** and A ... Z *are* **Type Expressions**
Sum :=	MySum<...> = | ***A*** of **(**A **| Axiom)** | ... | ***Z*** of **(**Z **| Axiom)**	*where* MySum<...> *is the* **Sum Identifier** *and* ***A*** ... ***Z*** *are* **Case Identifiers** *and* A ... Z *are* **Type Expressions**
Type Identifier :=	**Product Identifier | Sum Identifier**	
Type Expression :=	**Meaning Type | Type Identifier**	
Type Parameters :=	**Type Identifier**< A, ..., Z; ***A***<A, ..., Z>; ...; ***Z***<...>>	*where* A ... Z *are* **Type Expressions** *and* ***A*** ... ***Z*** *are* **Category Identifiers** *used for constraining* A ... Z
Category :=	category MyCat<...> = | f : A | ... | g : Z	*where* MyCat<...> *is the* **Category Identifier** *and* f ... g *are* **Equivilence Identifiers** *and* A ... Z *are* **Types Expressions**
Witness :=	witness ***A*** = | f (a : A) ... (z : Z) : R = **Expression** | ... | g (a : A) ... (z : Z) : R = **Expression**	*where* ***A*** *is a* **Category Identifier** *and* f ... g *are* **Equivilence Identifiers** *and* a ... z *are* **Parameter Identifiers** *and* A ... Z, R *are* **Type Expressions**
Categorization :=	**Rule:** *iff type* A *has a witness for category* ***A,*** A *is allowable for type parameter categorized as* ***A***	

Line Comment :=	**Example:** // comment text
fun *a b* ... *z* -> *expr* **:=**	*a* (*b* (... *z.expr*))
a **->** *b* **:=**	_ = (_ : *a*) : *b*
() **:=**	**Explanation:** The unit type / value.
f . g **:=**	**Explanation:** Function composition.

Sedela Language Prelude

```
Any = Axiom "The universal base type."
Bool = Axiom "A binary type."
Real = Axiom "A real number type."
Whole = Axiom "A whole number type."
String = Axiom "A textual type."
Maybe<a> = | Some of a | None
Either<a, b> = | Left of a | Right of b
List<a> = | Nil | Link of (a, List<a>)
Map<a, b> = | Leaf of (a, b) | Node of (Map<a, b>, Map<a, b>)

category Semigroup<a> =
  | append : a -> a -> a

category Monoid<m; Semigroup<m>> =
  | empty : m

category Functor<f> =
  | map<a, b> : (a -> b) -> f<a> -> f<b>

category Pointed<p> =
  | pure<a> : a -> p<a>

category FunctorPointed<f; Functor<f>; Pointed<f>>

category Applicative<p; FunctorPointed<p>> =
  | apply<a, b> : p<a -> b> -> p<a> -> p<b>

category Monad<m; Applicative<m>> =
  | bind<a, b> : m<a> -> (a -> m<b>) -> m<b>

category Alternative<l; Applicative<l>> =
  | empty<a> : l<a>
  | choice : l<a> -> l<a> -> l<a>

category Comonad<c; Functor<c>> =
  | extract<a> : c<a> -> a
  | duplicate<a, b> : c<a> -> c<c<a>>
  | extend<a, b> : (c<a> -> b) -> c<a> -> c<b>

category Foldable<f> =
  | fold<a, b> : (b -> a -> b) -> f<a> -> b
```

```
category Traversable<t; Functor<t>; Foldable<t>> =
  | traverse<a, b, p; Applicative<f>> : (a -> p<b>) -> t<a> -> p<t<b>>

category Functor2<g; Functor<g>> =
  | map2<a, b, c> : g<a> -> g<b> -> g<c>

category Producible<p; Functor2<p>> =
  | product<a, b> : p<a> -> p<b> -> p<(a, b)>

category Summable<s; Producible<s>> =
  | sum<a, b> : s<a> -> s<b> -> s<Either<a, b>>

category Foldable2<f> =
  | fold2<a, b, c> : (c -> a -> b -> c) -> f<a> -> f<b> -> c

// TODO: define the Arrow categories.

id a = a
const a _ = a
flip f a b = f b a
```

Nu Script Semantic Design (script code is in **bold**)

witness Monoid =
  | append = **+**
  | empty = **toEmpty -t-**

witness Monad =
  | pure = **pure**
  | map = **map**
  | apply = **app**
  | bind = **bind**

witness Foldable =
  | fold = **fold**

witness Functor2 =
  | map2 = **map2**

// TODO: define **product** and **sum** for AMSL so we can make a witness for Algebraic.

Property = Axiom "A property of a simulant."
Relation = Axiom "Indexes a simulant or event relative to the local simulant."
Address = Axiom "Indexes a global simulant or event."

get<a> : Property -> Relation -> a = Axiom "Retrieve a property of a simulant indexed by Relation."
set<a> : Property -> Relation -> a -> a = Axiom! "Update a property of a simulant indexed by Relation, then returns its value."

Stream<a> = Axiom "A stream of simulant property or event values."
getAsStream<a> : Property -> Relation -> Stream<a> = **getAsStream**
setAsStream<a> : Property -> Relation -> Stream<a> = **setAsStream**
makeStream<a> : Address -> Stream<a> = **makeStream**
mapStream<a, b> (a -> b) -> Stream<a> -> Stream<b> = **map**
foldStream<a, b> : (b -> a -> b) -> b -> Stream<a> -> b = **fold**
map2Stream<a, b, c> (a -> b -> c) -> Stream<a> -> Stream<b> -> Stream<c> = **map2**
productStream<a, b> : Stream<a> -> Stream<b> -> Stream<(a, b)> = **product**
sumStream<a, b> : Stream<a> -> Stream<b> -> Stream<Either<a, b>> = **sum**

Semantic Design for MetaFunctions (a replacement for micro-services - unrelated to Nu)

```
Symbol =
  | Atom of String
  | Number of String
  | String of String
  | Quote of Symbol
  | Symbols of List<Symbol>
symbolToString (symbol : Symbol) : String = Axiom "Convert a symbol to string."
symbolFromString (str : String) : Symbol = Axiom "Convert a string to a symbol."

Vsync<a> = Axiom "The potentially asynchronous monad such as the one defined by Prime."
vsyncBind<a, b> (vsync : Vsync<a>) (f : a -> Vsync<b>) : Vsync<b> = Axiom "Create a potentially asynchronous operation."
vsyncReturn<a> (a : a) : Vsync<a> = Axiom "Create a potentially asynchronous operation that return the result 'a'."
witness Monad =
  | bind = vsyncBind
  | return = vsyncReturn

IPAddress = String
NetworkPort = Whole
Endpoint = (IPAddress, NetworkPort)
Intent = String // the intended meaning of a MetaFunction (indexes a MetaFunction from a Provider - see below)

Container = Intent -> Symbol -> Vsync<Symbol>
Provider = | Endpoint | Container
MetaFunction = Provider -> Intent -> Symbol -> Vsync<Symbol>

makeContainer (asynchrounous : Bool) (repositoryUrl : String) (credentials : (String, String)) (envDeps : Map<String, Any>) :
Container = Axiom "Make a container configured with its Vsync as asyncronous or not, built from source pulled from the givern
GIT url, and provided the given environmental dependencies."

attachDebugger (container : Container) = Axiom! "Attach debugger to code called inside the given container."

call (mfn : MetaFunction) provider intent args : Vsync<Symbol> = mfn provider intent args
```