2018

A Historical Architectural Tour of PowerShell (Part 1)

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Agenda

- This is round 1 of a 2 round set of talks.

```
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```

- In this session, we're going to trace PowerShell's evolution from the beginning up to shipping V1 in 2006
- We'll look at some of the technical, cultural and business forces that drove this evolution
- The goal of these talks is both to present and to gather interesting (and hopefully useful) historical aspects of PowerShell's evolution.
  - The plan is to put all of this information into the GitHub repo so it will be available to everyone.
  - So if you have suggestions, anecdotes, questions or complaints, please let me know.

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Architecture (and Beer) Makes #JoeyHappy

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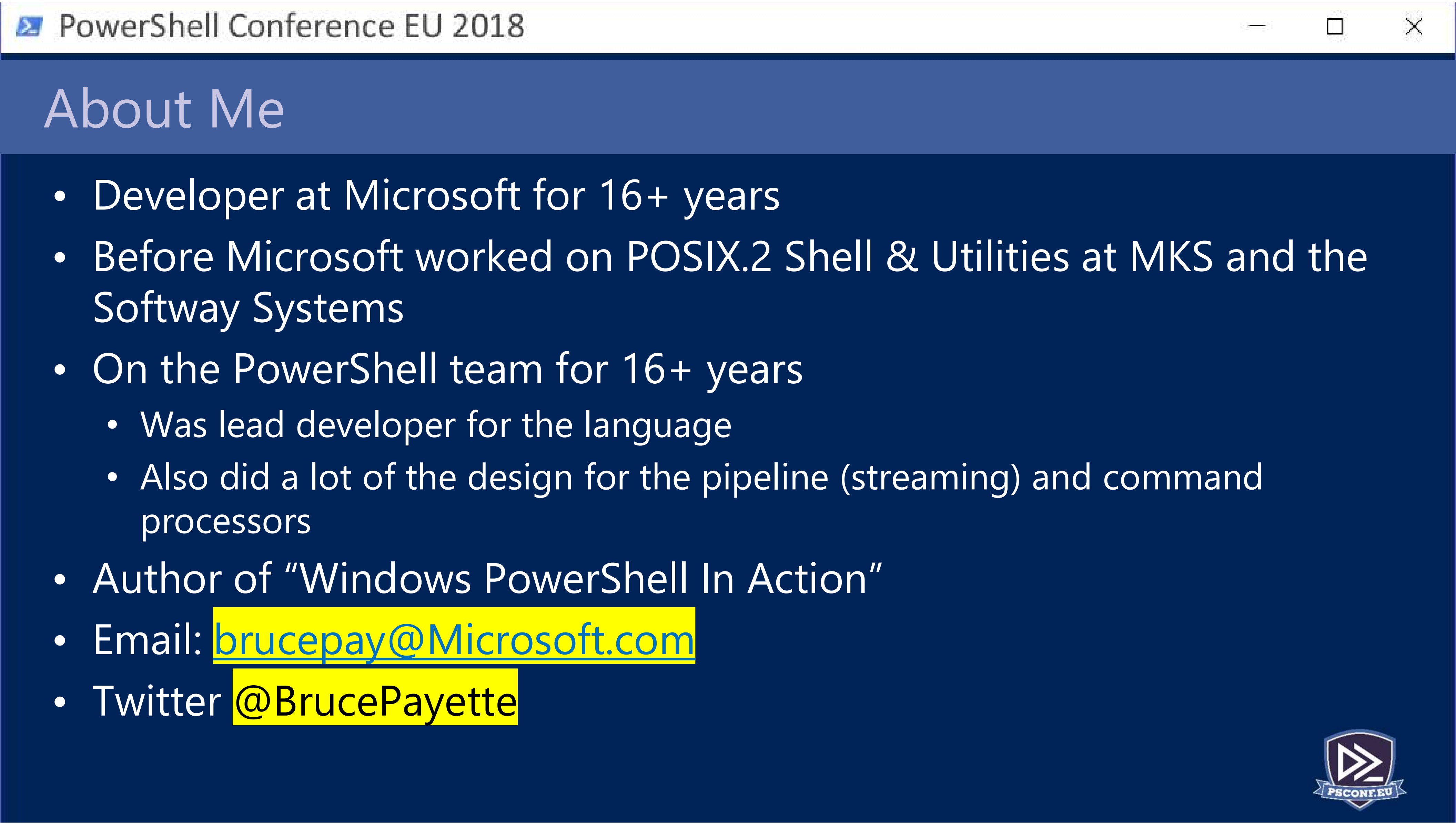
This is important stuff!

- We thought about (almost) everything in PowerShell
  - *Very little is arbitrary; most everything is intentional*
  - Doesn’t mean we got it all right
  - Doesn’t mean we thought *of* everything…

Those who forget the past are doomed to relive it.



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About Me

- Developer at Microsoft for 16+ years
- Before Microsoft worked on POSIX.2 Shell & Utilities at MKS and the Softway Systems
- On the PowerShell team for 16+ years
  - Was lead developer for the language
  - Also did a lot of the design for the pipeline (streaming) and command processors
- Author of “Windows PowerShell In Action”
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In the beginning…

- (Power)Shell development started in 2001
  - A project was funded out of the India Development Center (IDC) to investigate improving the shell experience on Windows.
  - Code name was *Kermit* (for the hermit crab who lost his shell)
  - Staffed with people from the Interix/Services for Unix (SFU) team with Unix shell and utilities experience
- Why was this funded?
  - Technology driver: Survey Says: Automation on Windows was hard
    - 10x effort, 10x time to achieve the same goals as on Unix
  - Business driver: Unix esp. Linux and the LAMP stack were hot (competition)
  - Culture(?): 1 server wasn’t enough and automation was key to managing large (and getting larger) groups of servers.
- But where’s Jeffrey in all this activity ???

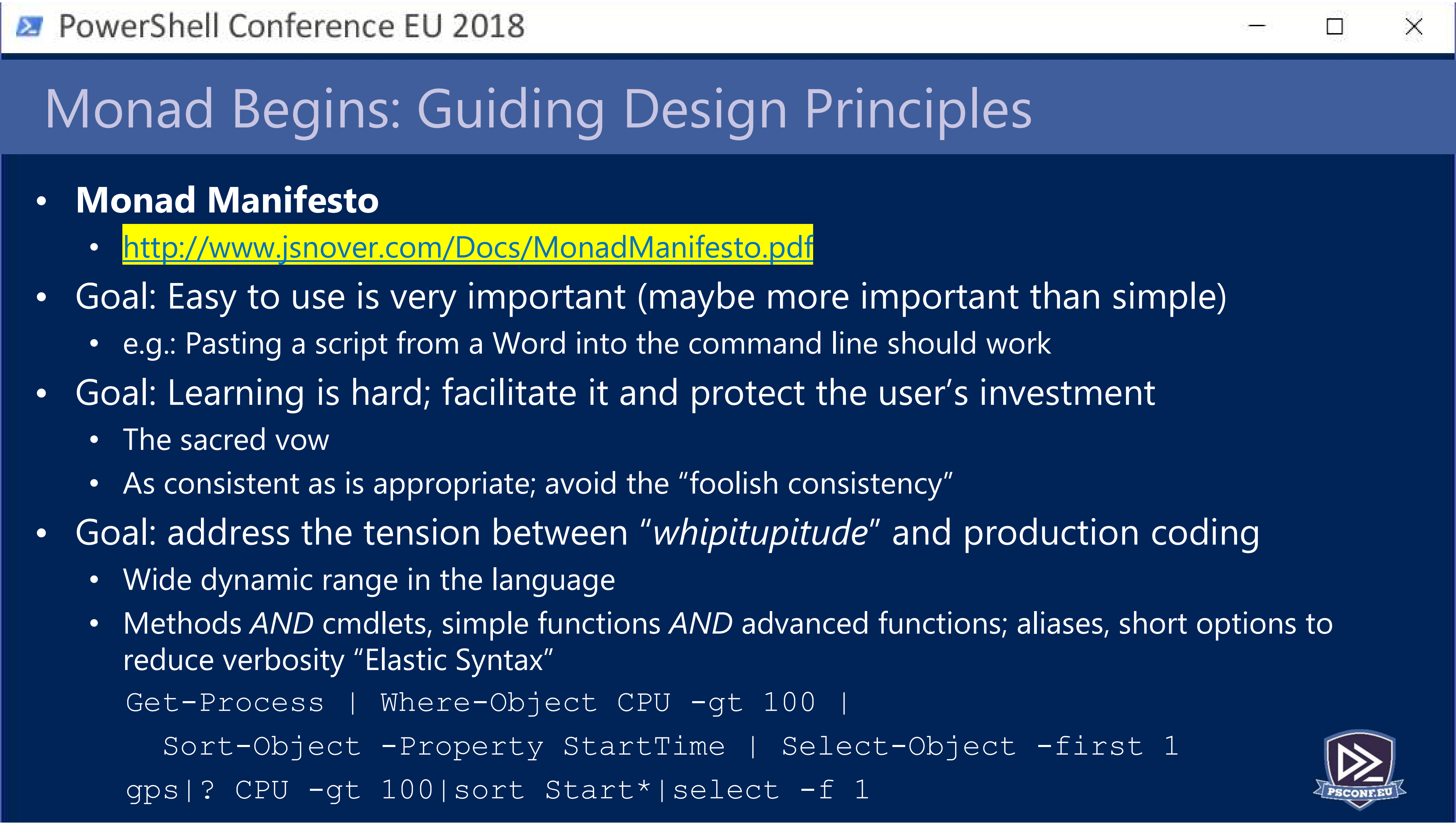
Meanwhile, in Building 42…

- Jeffrey was madly building a prototype of a command line experience based on a radically new set of concepts
  - A command language based on the composition of Functional Units (or FU for short) and an extended mutable type system
- The prototype used a different model of composition compared to what we eventually shipped in PowerShell.
  - An FU was an “extension” of the command before it which looked something like:

    ```
    process/get /name:c* /sort: CPU /select: 5
    ```

  - Instead of the final PowerShell syntax (note: order matters)

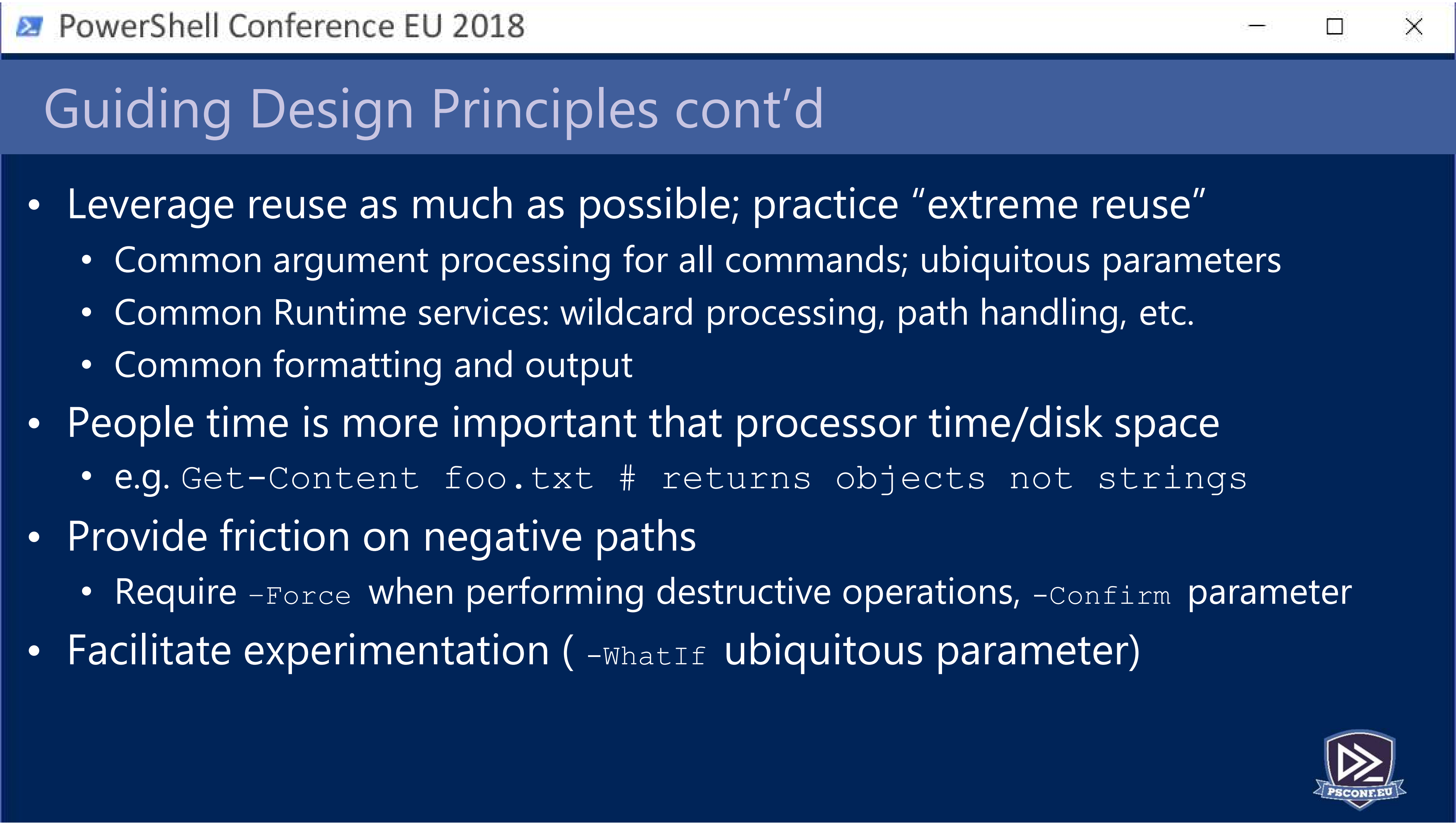
    ```
    Get-Process -Name c* | sort CPU | select -first 5
    ```



Monad Begins: Guiding Design Principles

- **Monad Manifesto**
  - http://www.jsnover.com/Docs/MonadManifesto.pdf
- Goal: Easy to use is very important (maybe more important than simple)
  - e.g.: Pasting a script from a Word into the command line should work
- Goal: Learning is hard; facilitate it and protect the user's investment
  - The sacred vow
  - As consistent as is appropriate; avoid the "foolish consistency"
- Goal: address the tension between "*whipitupitude*" and production coding
  - Wide dynamic range in the language
  - Methods *AND* cmdlets, simple functions *AND* advanced functions; aliases, short options to reduce verbosity "Elastic Syntax"

```
Get-Process | Where-Object CPU -gt 100 |
  Sort-Object -Property StartTime | Select-Object -first 1
gps|? CPU -gt 100|sort Start*|select -f 1
```



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Guiding Design Principles cont'd

- Leverage reuse as much as possible; practice "extreme reuse"
  - Common argument processing for all commands; ubiquitous parameters
  - Common Runtime services: wildcard processing, path handling, etc.
  - Common formatting and output
- People time is more important that processor time/disk space
  - e.g. `Get-Content foo.txt # returns objects not strings`
- Provide friction on negative paths
  - Require `-Force` when performing destructive operations, `-Confirm` parameter
- Facilitate experimentation (`-WhatIf` ubiquitous parameter)

Project begins: we acquire a team…

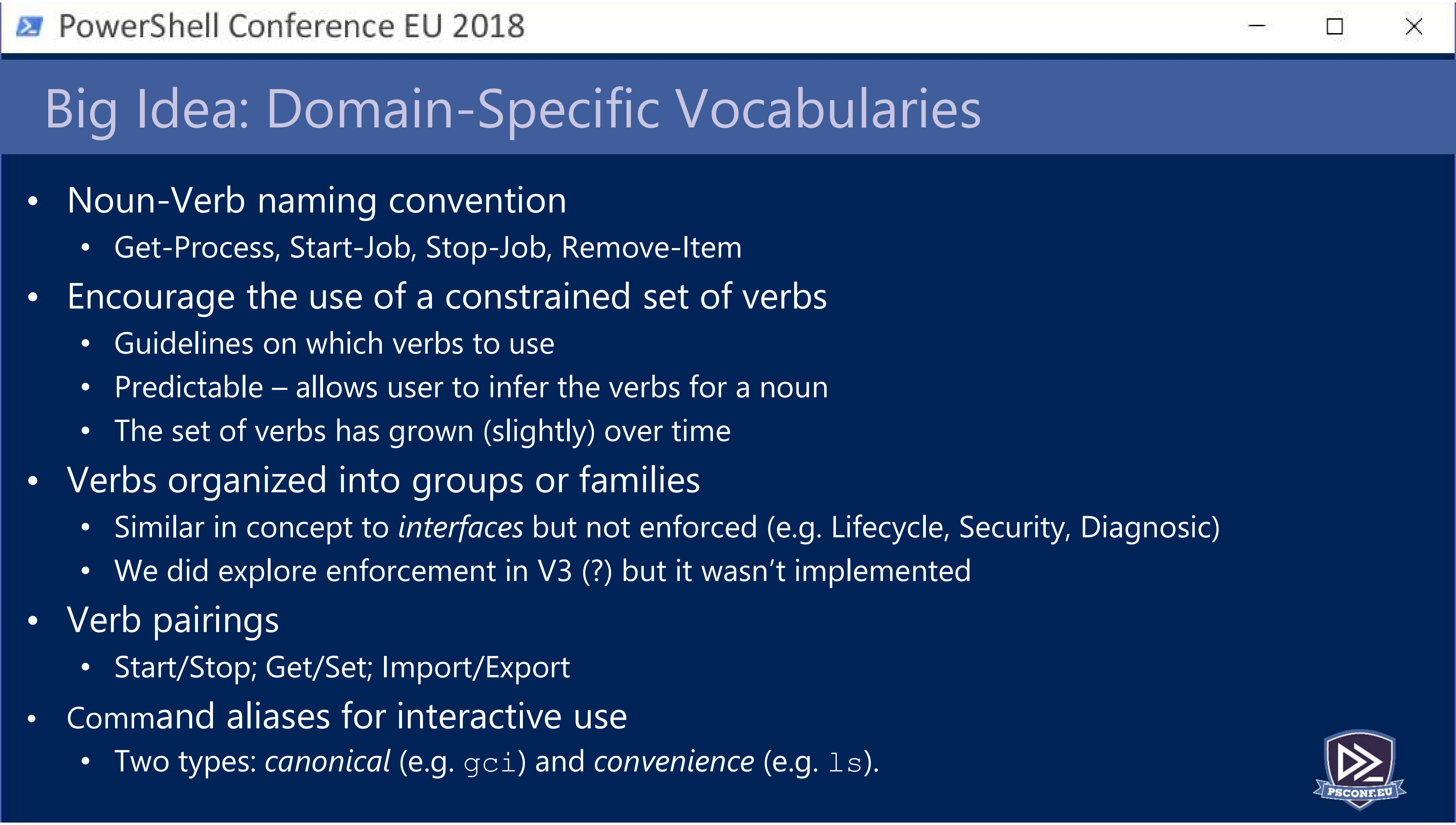
- Staffed out of IDC in Hyderabad, India
  - Architecture owners in Redmond
  - Development and Test to be done in India
- But radical experimentation does not flourish with this level of geographic distribution
  - It was taking too long to round-trip ideas
  - First development then test were pulled back to Redmond
- We acquire another team
  - Built from the Windows Management Pack team so lots of Windows management experience.
  - Now we can begin in earnest…
- We change buildings. And again. And again. (6x in 2 years)

Oh, and be ready to ship in 2 weeks…

- The *Longhorn time frame*
  - Microsoft was dipping a toe into the idea of continuous delivery
  - It was an exciting time…
- This meant that the initial release plan for PowerShell wouldn’t have been much more than Jeffrey’s prototype slightly cleaned up
  - No performance work
  - No coverage
  - No ability to write scripts or functions
  - There would have only been an interactive experience
- This was not ideal.
- Fortunately it didn’t happen ☺

We Had Big Ideas

- “Big Ideas” represent some of the major design elements of PowerShell
  - Concrete design decisions rather than abstract principles



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Big Idea: Domain-Specific Vocabularies

- Noun-Verb naming convention
  - Get-Process, Start-Job, Stop-Job, Remove-Item
- Encourage the use of a constrained set of verbs
  - Guidelines on which verbs to use
  - Predictable – allows user to infer the verbs for a noun
  - The set of verbs has grown (slightly) over time
- Verbs organized into groups or families
  - Similar in concept to *interfaces* but not enforced (e.g. Lifecycle, Security, Diagnosic)
  - We did explore enforcement in V3 (?) but it wasn't implemented
- Verb pairings
  - Start/Stop; Get/Set; Import/Export
- Command aliases for interactive use
  - Two types: *canonical* (e.g. `gci`) and *convenience* (e.g. `ls`).

Big Idea: Universal command-line parsing

- Unlike most shells, cmdlets are not responsible for parsing their own parameters
- Common parameter parsing code shared by all types of commands
  - Command-specific parameter *binding*

```
…\src\System.Management.Automation\engine\*parameterbinder*.cs
```

- This gives us the broad consistency across commands
  - Except for native commands ☹ which do their own argument parsing
  - Native commands on Unix are pretty regular, commands on Windows – not so much
  - Native command parameter binder takes the parsed parameters and tries to put them back into something like what the user typed. Sometimes it works, sometimes it doesn’t

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Big Idea: Declarative Parameter Constraints

- Rather than writing imperative code to do checking, use declarative attributes to deal with constraints:
  - `[ValidateIsNotNullOrEmpty]`, `[ValidateRange()]`, `[ValidateSet()]`
- These attributes both simplified the code and resulted in a consistent experience (i.e. common error messages)
- Sometimes the consistent experience could be suboptimal
  - e.g. with `[ValidatePattern(“[0-9]+”)]` the error message would say “failed to match pattern [0-9]+” instead of “number expected”
- And sometimes it just didn’t work, per this comment:

…\src\Microsoft.PowerShell.Commands.Management\commands\management\Process.cs

```
// 2004/12/17-XXXX ProcessNameGlobAttribute was deeply wrong.
// For example, if you pass in a single Process, it will match
// all processes with the same name.
// I have removed the globbing code.
```

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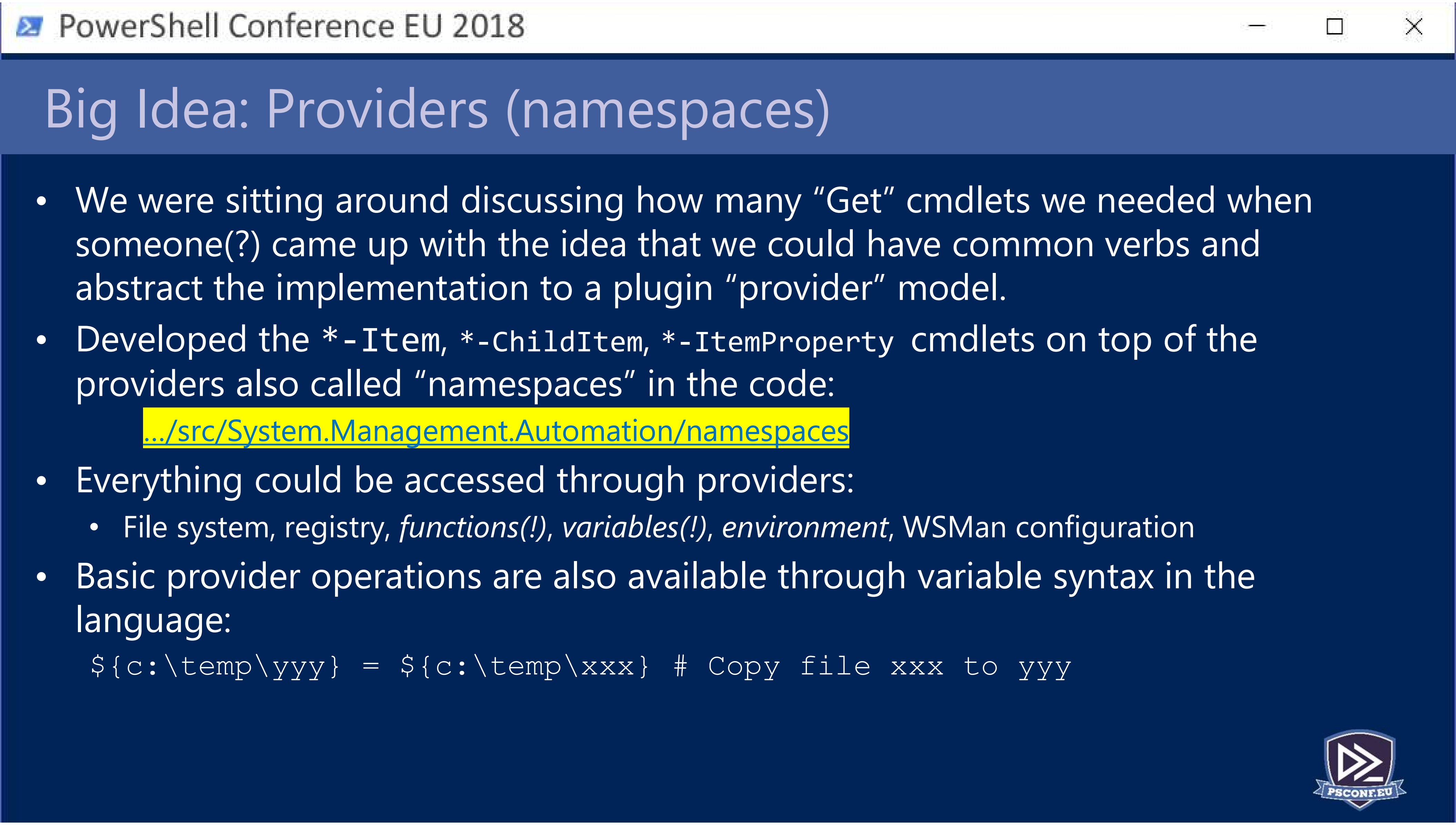

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Big Idea: Providers (namespaces)

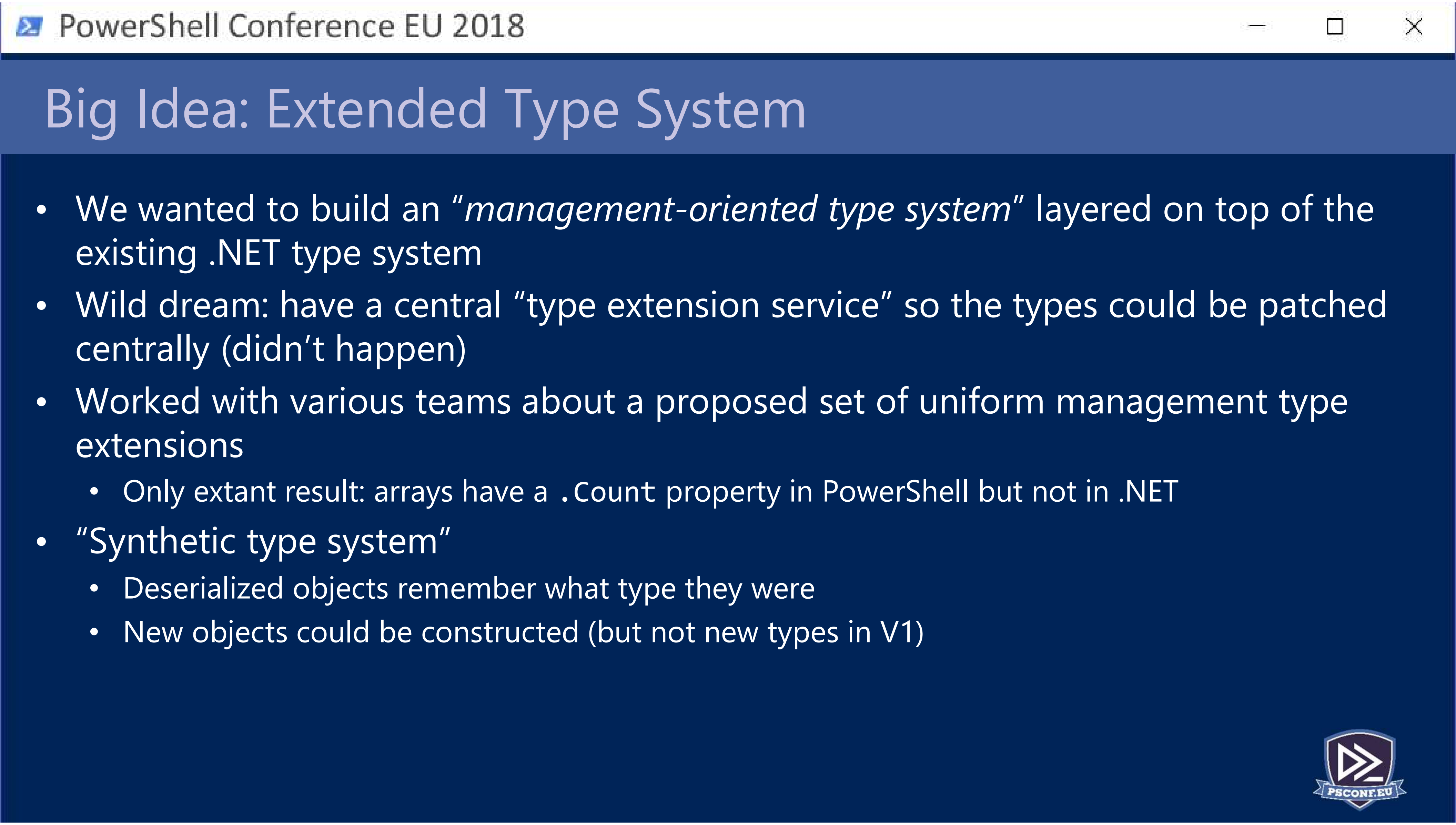
- We were sitting around discussing how many “Get” cmdlets we needed when someone(?) came up with the idea that we could have common verbs and abstract the implementation to a plugin “provider” model.
- Developed the `*-Item`, `*-ChildItem`, `*-ItemProperty` cmdlets on top of the providers also called “namespaces” in the code:

  .../src/System.Management.Automation/namespaces
- Everything could be accessed through providers:
  - File system, registry, *functions(!)*, *variables(!)*, *environment*, WSMan configuration
- Basic provider operations are also available through variable syntax in the language:

```
${c:\temp\yyy} = ${c:\temp\xxx} # Copy file xxx to yyy
```

Big Idea: Streaming

- The Unix shell pipeline was definitely a feature we wanted in PowerShell
  - But Unix used multiple processes to do this; commands were external executables
  - Commands in PowerShell all run *in-process* with the engine so the traditional approach couldn’t work
- Next we looked at using 1 thread per command
  - More light weight than processes but still heavy
- Solution was to sequence objects through the pipeline 1 at a time
- Problem (we still have today) is that when streaming, there is ambiguity as to whether or no the single object is scalar or an array.
  - Mitigate with @(command)
- Visible in the API as public class `SteppablePipeline`
  - Wraps the internal Pipeline class
  - Introduced in V2



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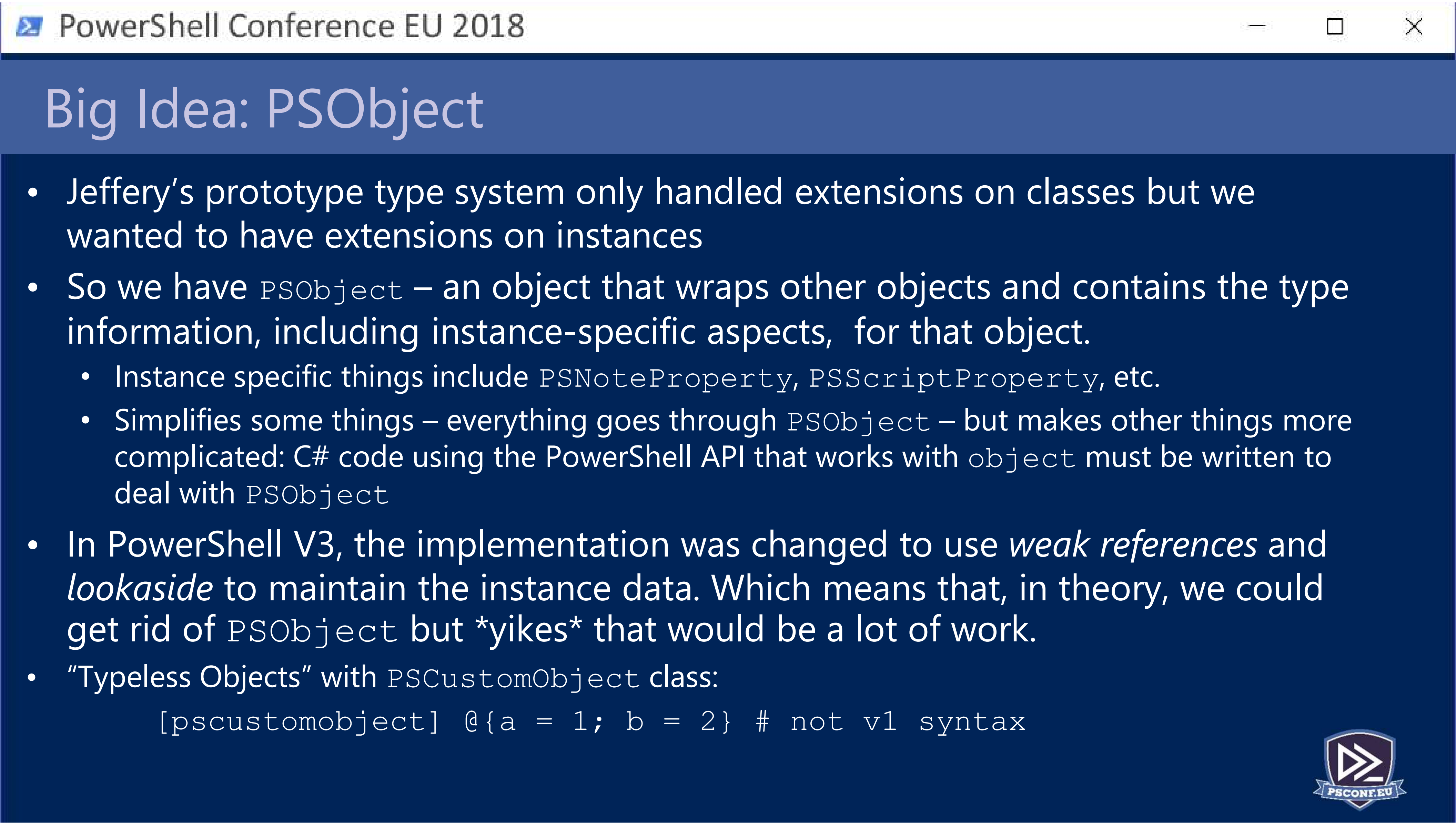
Big Idea: Extended Type System

- We wanted to build an “*management-oriented type system*” layered on top of the existing .NET type system
- Wild dream: have a central “type extension service” so the types could be patched centrally (didn’t happen)
- Worked with various teams about a proposed set of uniform management type extensions
  - Only extant result: arrays have a `.Count` property in PowerShell but not in .NET
- “Synthetic type system”
  - Deserialized objects remember what type they were
  - New objects could be constructed (but not new types in V1)



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Big Idea: PSObject

- Jeffery’s prototype type system only handled extensions on classes but we wanted to have extensions on instances
- So we have `PSObject` – an object that wraps other objects and contains the type information, including instance-specific aspects, for that object.
  - Instance specific things include `PSNoteProperty`, `PSScriptProperty`, etc.
  - Simplifies some things – everything goes through `PSObject` – but makes other things more complicated: C# code using the PowerShell API that works with `object` must be written to deal with `PSObject`
- In PowerShell V3, the implementation was changed to use *weak references* and *lookaside* to maintain the instance data. Which means that, in theory, we could get rid of `PSObject` but *yikes* that would be a lot of work.
- “Typeless Objects” with `PSCustomObject` class:

```
[pscustomobject] @{a = 1; b = 2} # not v1 syntax
```

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Error Handling

- Universal streams – Error, Warning, Verbose, Debug (, Logging)
- Live error logging in `$Error`
- Terminating vs Non-terminating errors
  - Non-terminating errors for shell-like semantics
  - NOT different types of errors; different dispositions (different *Error Actions*)
- Checking command execution status
  - Errors go to a stream – hard to test; check `$?` to see if a command had an error
  - `$LASTEXITCODE` for status of native commands
- Exceptions !!!!
  - trap statement – taken from Perl 6; like VB OnError statement
    - $_ is the error record, not the exception inside a trap
  - Lexically scoped; can't set a durable trap
  - `throw` statement

Break and Continue

- Break out of loops; continue in loops
- Can break to a labelled loop; *break label is an expression (!)*

```
$l = label ; :label while (1) { while (1) { break $l }
```

- Uncaught breaks propagate until they are caught
  - If they aren't caught, they stop the current execution
  - Yeah it's weird; limited utility
  - Somewhat like C's non-local goto `setjmp/longjmp`
- `break` and `continue` in traps
  - Continue in a `trap` resumes execution after the statement in the current context that caused the trap.

Big Idea: Security, Security, Security

- Secure by default
- Threat modelling
    - Thread, ***Asset***, Mitigation
    - We had some problems figuring out what an asset was
- Struggled with Code Access Security (CAS)
    - Was designed to allow trusted code to call untrusted code while restricting capabilities - too complicated to use
- For PowerShell, the trust boundary is at the runspace
    - Untrusted code must cross the runspace boundary (see part 2 of this talk.)
- ExecutionPolicy – *it's a safety belt, not a door look*
    - Reduces risk by reducing possibility of accidents

The Implementation

Implementation…

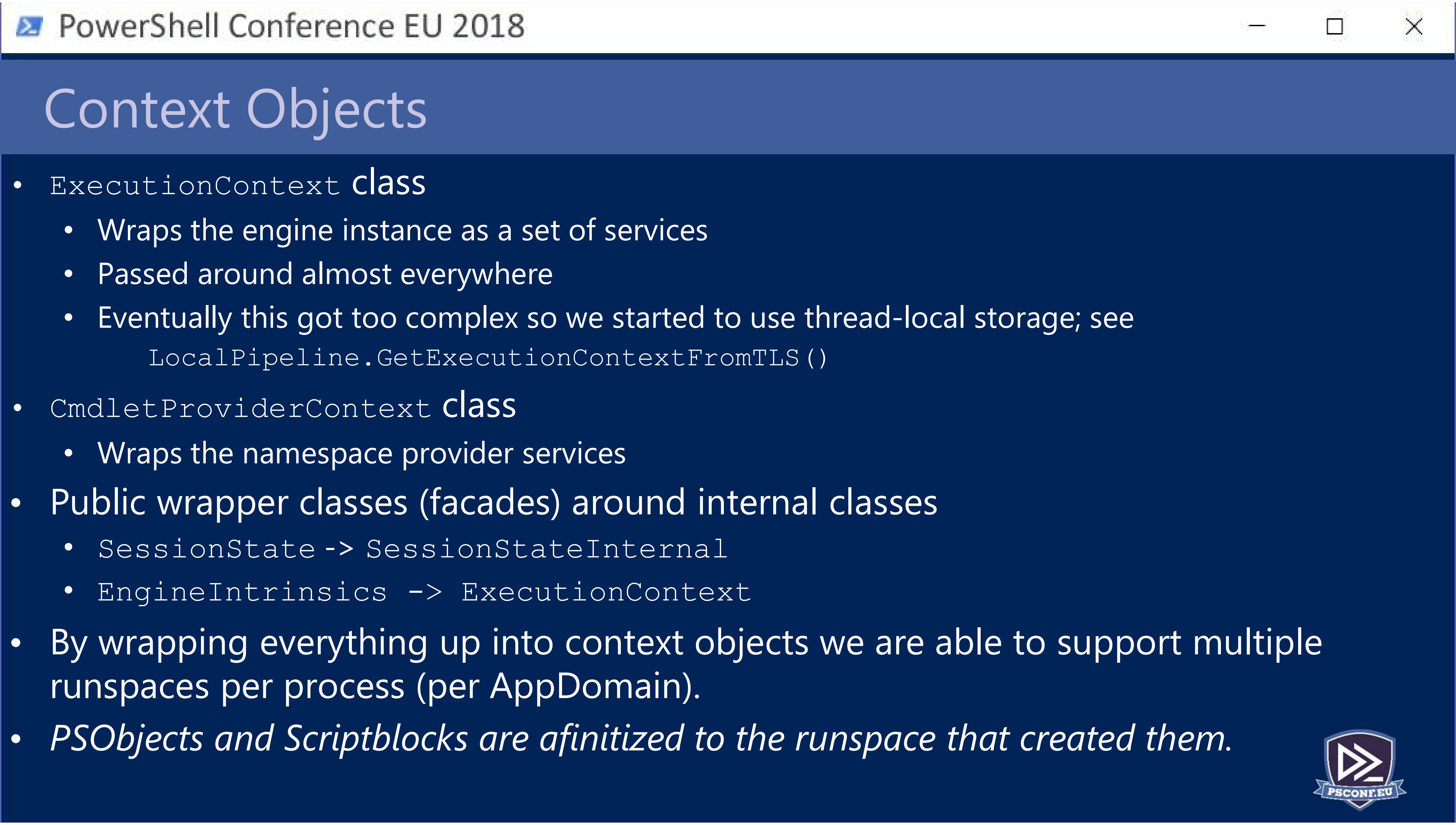
- Initial engine design was highly componentized; most of there components live in `…/src/System.Management.Automation/engine/`
- Some of the pieces:
  - Runspace configuration (supplanted by InitialSessionState in V2)
  - Language Tokenizer, Parser & Executor
  - Execution Context (includes session state)
  - Command Discovery (subsystem to find commands)
  - Pipeline processor
    - Command processors
  - Error handling subsystem
- With this design you had to build your own shell – high barrier to entry
- To simplify the API, everything was bundled up into ***Runspaces***.
  - A Runspace is a space where you run things. Why is that so hard?

Followed .NET Guidelines

- Followed .NET guidelines *as they existed at the time*
- Sealed all classes that weren’t explicitly extensible
  - Intended to mitigate versioning
  - Kind of a pain; derivation is useful
- Made everything internal unless it was a explicit API
  - Reduce support costs; `LanguagePrimitives` should have been public
- APIs that return collections should never return null
  - return empty collection instead.
- Favor generic collections over polymorphic collections
  - `List<int>` instead of `ArrayList`
- We also broke a bunch over rules (see pragmas in code)
  - e.g. “Properties should not return array”

Lots of (Informal) Use of Design Patterns

- We used a lot of OO design patterns in the code
  - *Prefer composition over inheritance*
- Adapter pattern
  - Type Adapters (Extension point)
- Façade pattern
  - *Command Processors* – hides the implementation differences in various command types
    - Defined (but not public) extension point; other command types could be added
- Strategy
  - Command Parameter Binders
- Factory
  - `RunspaceFactory`



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Context Objects

- `ExecutionContext` class
  - Wraps the engine instance as a set of services
  - Passed around almost everywhere
  - Eventually this got too complex so we started to use thread-local storage; see
    `LocalPipeline.GetExecutionContextFromTLS()`
- `CmdletProviderContext` class
  - Wraps the namespace provider services
- Public wrapper classes (facades) around internal classes
  - `SessionState -> SessionStateInternal`
  - `EngineIntrinsics -> ExecutionContext`
- By wrapping everything up into context objects we are able to support multiple runspaces per process (per AppDomain).
- *PSObjects and Scriptblocks are afinitized to the runspace that created them.*

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The PowerShell Language

The Language

- In the original architecture, the language was conceived as being separate from the PowerShell engine.
  - In theory, you would be able to substitute difference languages
- In practice, over time the language and the engine became deeply intermixed
  - E.g. the engine uses formatting and output which can have script properties which requires the language
- Starting with version 2, you can *use* PowerShell from other languages using the PowerShell API.

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Language roots…

- Started with the IEEE POSIX.2 shell grammar (essentially the Korn Shell (ksh))
  - From the shell we got `$variables`, `$( subexpression ), $?,` pipelines (|), dot-sourcing, *direct execution* of external programs
- Parameter syntax inspired, in part, by DCL (DEC Command Language)

```
Get-Something -parameter: $argument
```

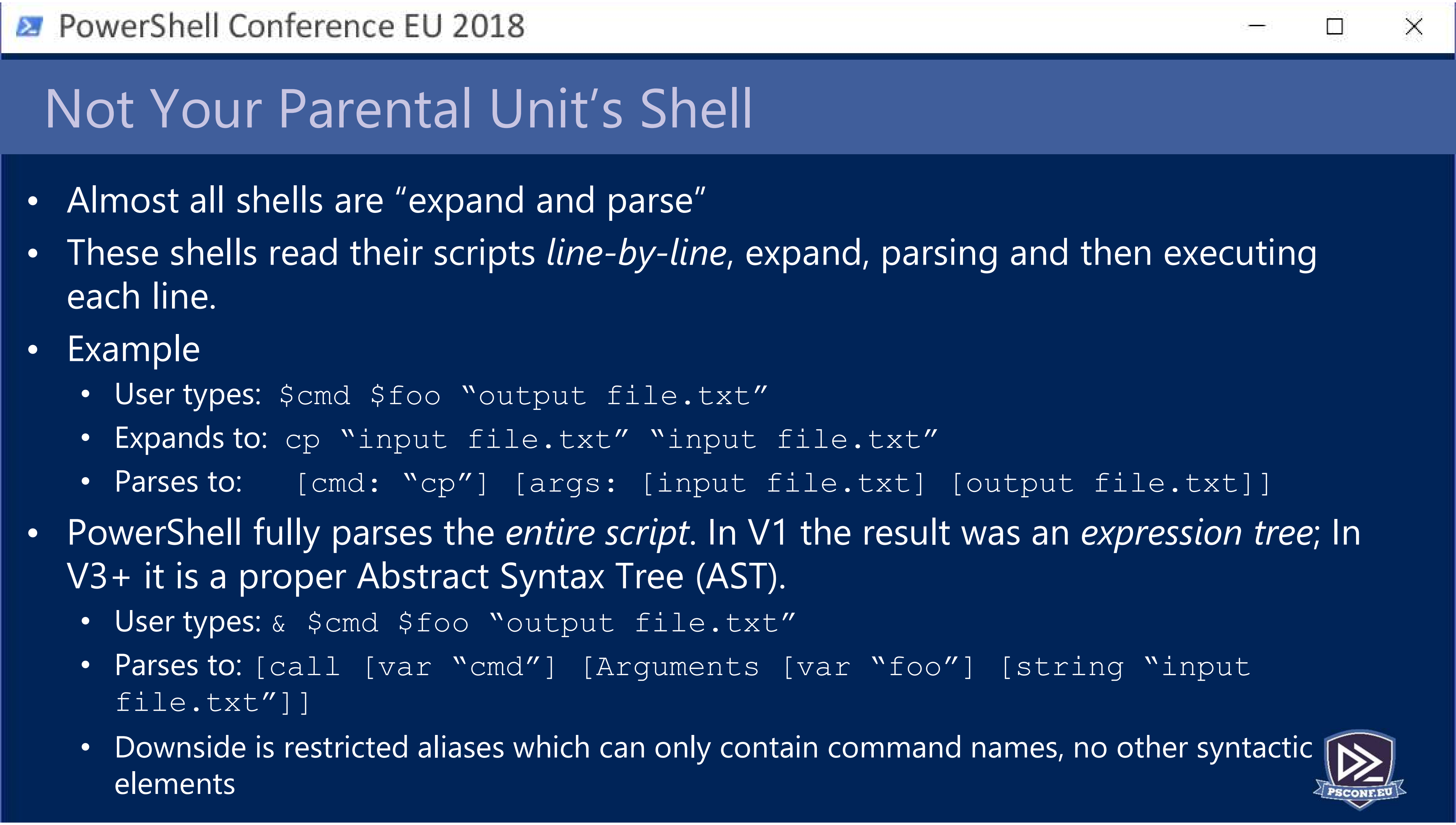
- For concepts that weren't in the POSIX Shell, we started by adapting elements of Perl:
  - Perl was pretty much the dominant scripting language on the Internet.
  - Perl had arrays, hashtables, regular expression all of which we wanted
  - Super significant – Perl had CPAN (Comprehensive Perl Archive Network)
  - Syntax elements we retained from PERL
    - $_, the use of @ in places (@(), @(array subexpression)), & call operator, regular expressions

The language evolves…

- But in the end, Perl was kind of … ummm … icky

  “Line noise should not compile”

- So we switched our syntax model to align with C#
  - which essentially means aligning, to a greater or lesser extent, with C, C++, Java, AWK, Go, CShell, Objective-C, PHP, PERL etc.
- The value proposition became, in part: if you learned PowerShell, you could move to C# pretty easily and if you knew C#, you could pick up PowerShell pretty easily.
  - Protects the student’s investment
  - Not sure how well that worked sometimes ☺



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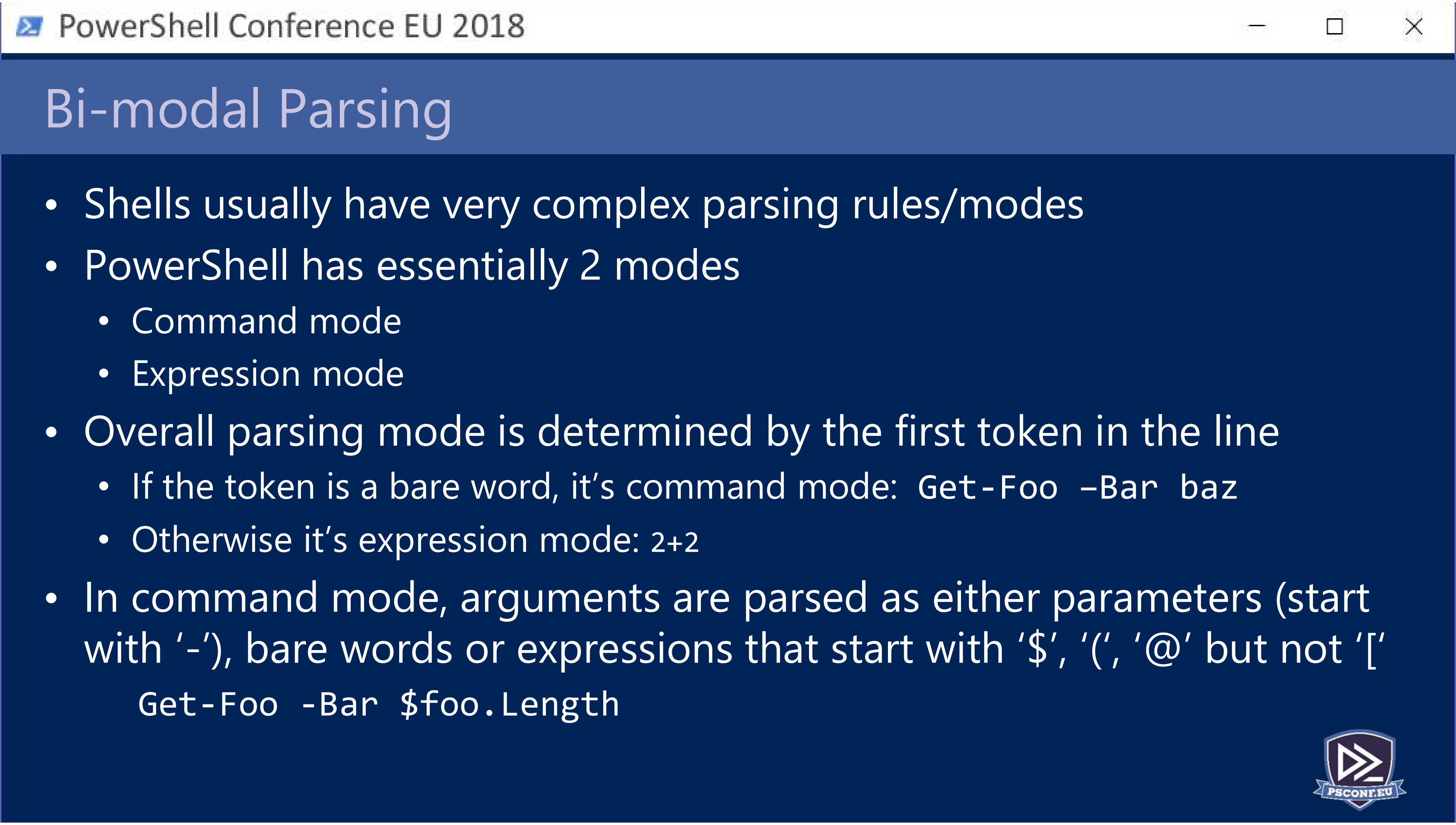
Not Your Parental Unit’s Shell

- Almost all shells are “expand and parse”
- These shells read their scripts *line-by-line*, expand, parsing and then executing each line.
- Example
  - User types: `$cmd $foo “output file.txt”`
  - Expands to: `cp “input file.txt” “input file.txt”`
  - Parses to: `[cmd: “cp”] [args: [input file.txt] [output file.txt]]`
- PowerShell fully parses the *entire script*. In V1 the result was an *expression tree*; In V3+ it is a proper Abstract Syntax Tree (AST).
  - User types: `& $cmd $foo “output file.txt”`
  - Parses to: `[call [var “cmd”] [Arguments [var “foo”] [string “input file.txt”]]`
  - Downside is restricted aliases which can only contain command names, no other syntactic elements



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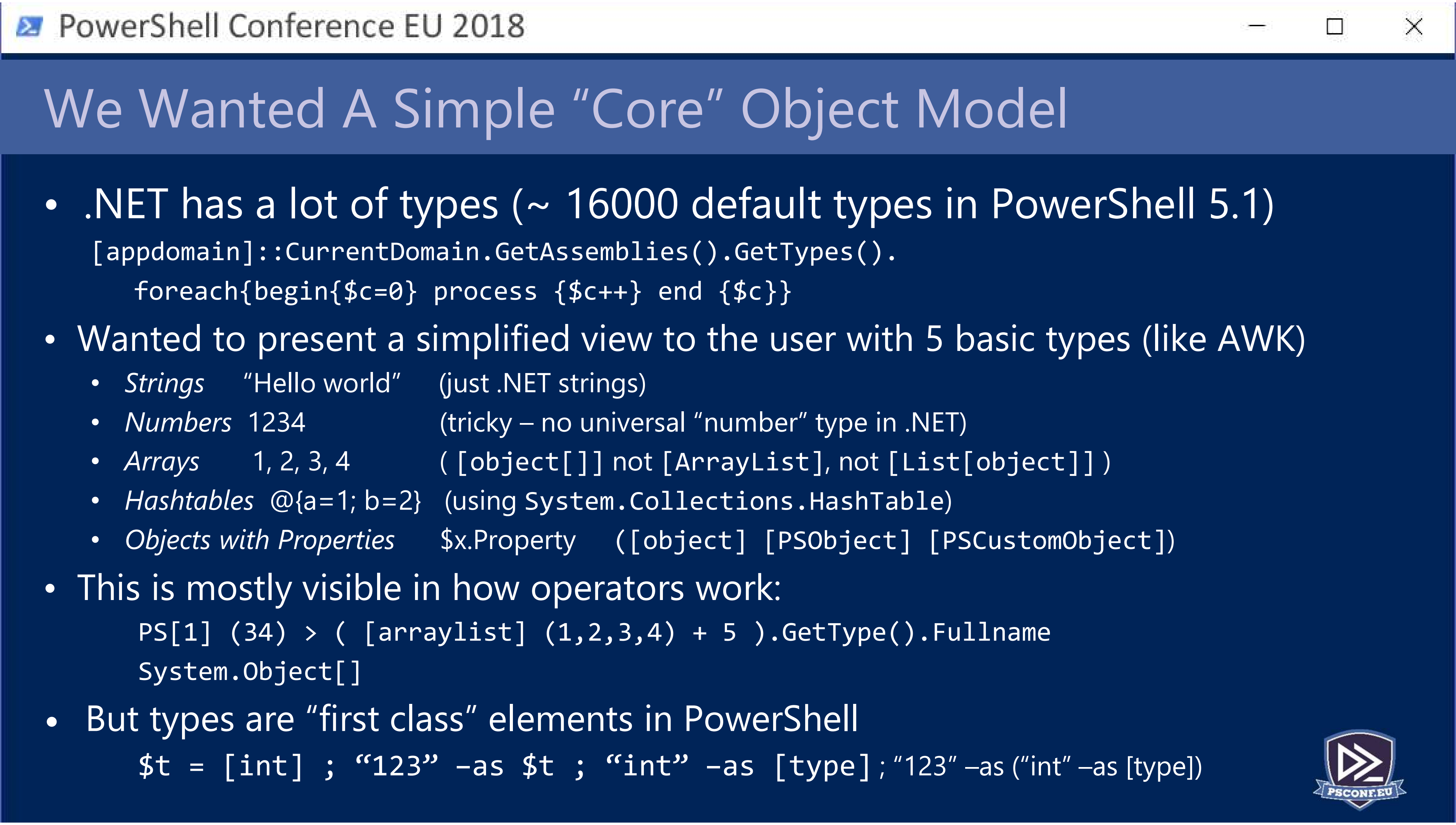
Bi-modal Parsing

- Shells usually have very complex parsing rules/modes
- PowerShell has essentially 2 modes
  - Command mode
  - Expression mode
- Overall parsing mode is determined by the first token in the line
  - If the token is a bare word, it's command mode: `Get-Foo –Bar baz`
  - Otherwise it's expression mode: `2+2`
- In command mode, arguments are parsed as either parameters (start with '-'), bare words or expressions that start with '$', '(', '@' but not '['

```
Get-Foo -Bar $foo.Length
```



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We Wanted A Simple “Core” Object Model

- .NET has a lot of types (~ 16000 default types in PowerShell 5.1)

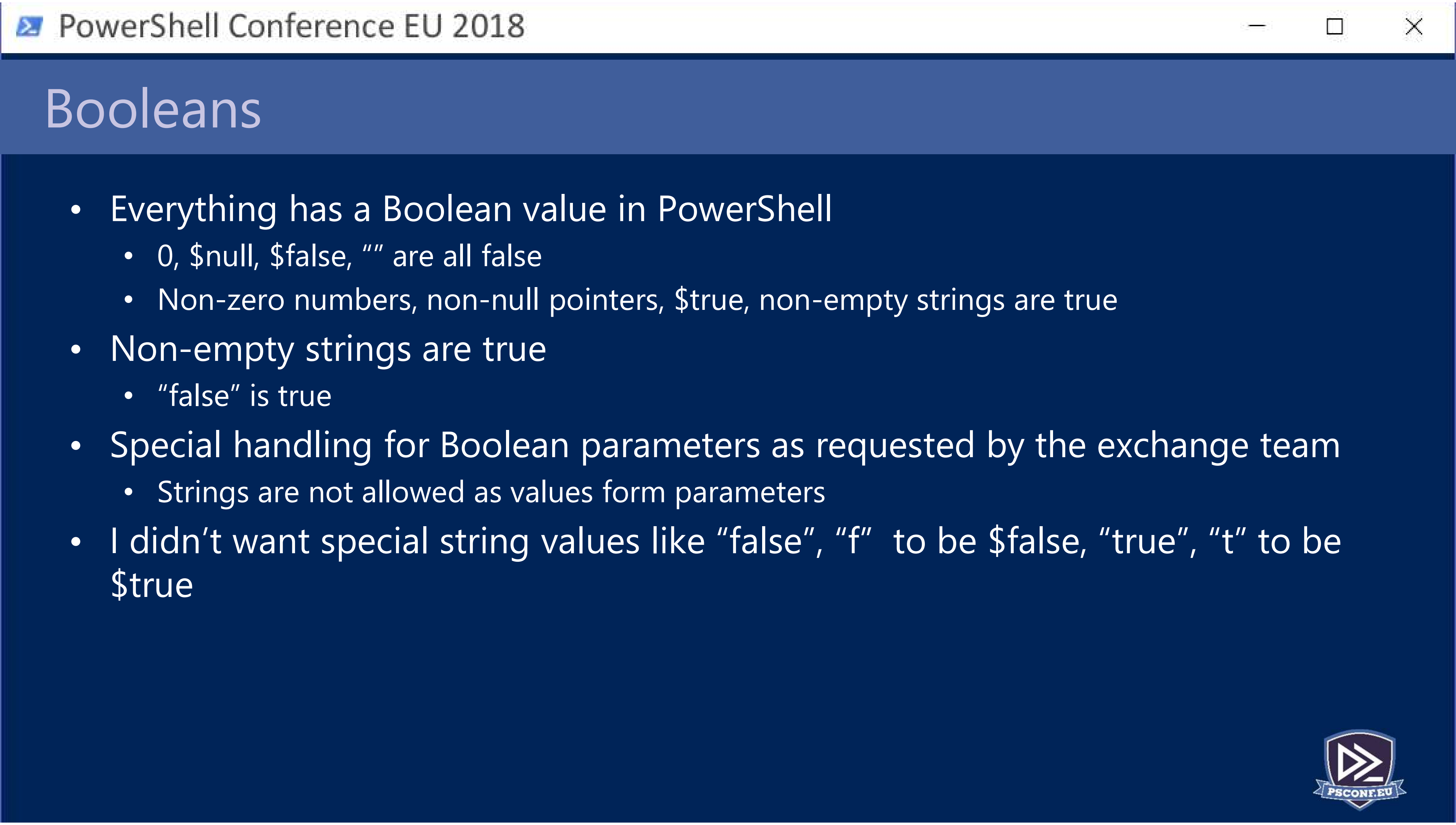
```
[appdomain]::CurrentDomain.GetAssemblies().GetTypes().
   foreach{begin{$c=0} process {$c++} end {$c}}
```

- Wanted to present a simplified view to the user with 5 basic types (like AWK)
  - *Strings* “Hello world” (just .NET strings)
  - *Numbers* 1234 (tricky – no universal “number” type in .NET)
  - *Arrays* 1, 2, 3, 4 (`[object[]]` not `[ArrayList]`, not `[List[object]]`)
  - *Hashtables* @{a=1; b=2} (using `System.Collections.HashTable`)
  - *Objects with Properties* $x.Property (`[object] [PSObject] [PSCustomObject]`)
- This is mostly visible in how operators work:

```
PS[1] (34) > ( [arraylist] (1,2,3,4) + 5 ).GetType().Fullname
System.Object[]
```

- But types are “first class” elements in PowerShell

```
$t = [int] ; “123” -as $t ; “int” -as [type] ; “123” –as (“int” –as [type])
```



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Booleans

- Everything has a Boolean value in PowerShell
  - 0, $null, $false, “” are all false
  - Non-zero numbers, non-null pointers, $true, non-empty strings are true
- Non-empty strings are true
  - “false” is true
- Special handling for Boolean parameters as requested by the exchange team
  - Strings are not allowed as values form parameters
- I didn’t want special string values like “false”, “f” to be $false, “true”, “t” to be $true

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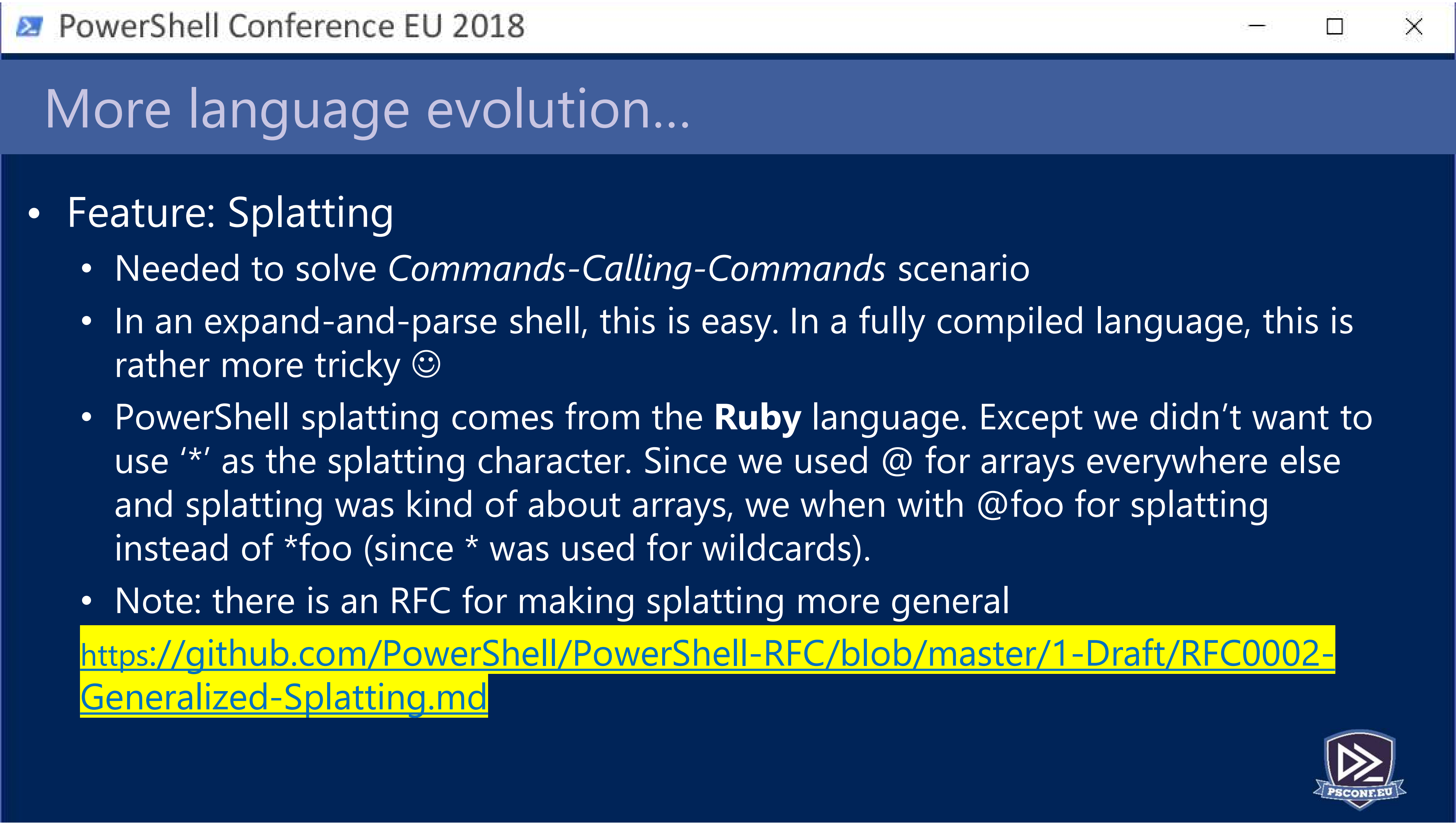


More language evolution…

- Feature: Splatting
  - Needed to solve *Commands-Calling-Commands* scenario
  - In an expand-and-parse shell, this is easy. In a fully compiled language, this is rather more tricky ☺
  - PowerShell splatting comes from the **Ruby** language. Except we didn't want to use '*' as the splatting character. Since we used @ for arrays everywhere else and splatting was kind of about arrays, we when with @foo for splatting instead of *foo (since * was used for wildcards).
  - Note: there is an RFC for making splatting more general

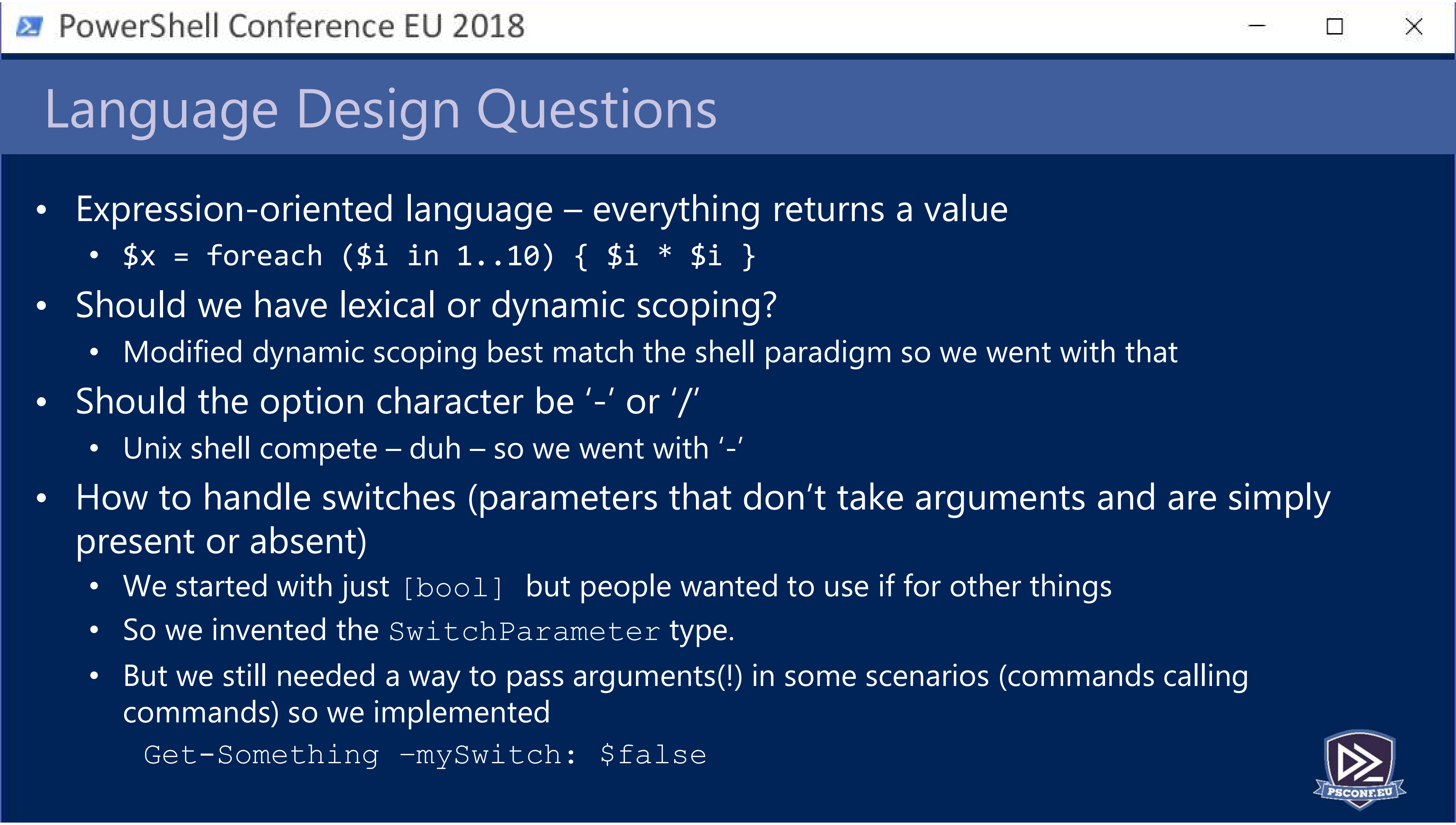
https://github.com/PowerShell/PowerShell-RFC/blob/master/1-Draft/RFC0002-Generalized-Splatting.md

Scriptblocks and the call (&) operator …

- We needed the call operator to do indirect invocations, again because we're not expand and parse
  - `& “a command with spaces” so there`
- MMC team requested a way to have isolated (anonymous) blocks of code they could call later
  - This seemed like a job for *lambda functions*
  - We wanted them to be friendly to non-coders so they became *Scriptblocks*.
  - Example with `foreach` and `where` cmdlets

    ```
    dir | where { $_.Length -gt 100 }
    ```
  - Users are not necessarily aware they are using lambdas
- Scriptblocks became the core of script execution scenarios, including things like .NET delegates which allowed WinForms and XAML scripting.
- Example: function definition through assignment:

  ```
  $function:bob = {param ($name) Write-Host “Hi $name, I’m Bob!”}
  ```



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Language Design Questions

- Expression-oriented language – everything returns a value
  - `$x = foreach ($i in 1..10) { $i * $i }`
- Should we have lexical or dynamic scoping?
  - Modified dynamic scoping best match the shell paradigm so we went with that
- Should the option character be '-' or '/'
  - Unix shell compete – duh – so we went with '-'
- How to handle switches (parameters that don't take arguments and are simply present or absent)
  - We started with just `[bool]` but people wanted to use if for other things
  - So we invented the `SwitchParameter` type.
  - But we still needed a way to pass arguments(!) in some scenarios (commands calling commands) so we implemented

```
Get-Something -mySwitch: $false
```

Language Questions cont'd

- Shells just deal with *strings* so everything is a *string*. PowerShell Lives in a world of objects but it had to *behave* like every other shell.
- Solution was to have *super-aggressive* type conversions
  - This means that the PowerShell runtime makes a lot of implicit guesses at the types you meant (but conversions do not chain implicitly)
- It does this by *searching* for a converter with the best type match
  - Type distance algorithm – in ambiguous cases, it computes a "distance" between the various candidate types and their target. Shortest distance wins.
  - Parameter binder doesn't do this. Binding is done in two passes:
    - Exact type match is required on first pass
    - *First* possible valid conversion is taken on the second pass.

Shipping Mon^h^h^h PowerShell

To Ship is to Choose.

… was like being a cockroach in a room full of cowboy boots.

-Jeffrey Snover

Shipping Is Fun!

- PowerShell started as an “independent” project inside Microsoft
  - Had it’s own build system, etc.
  - Would ship on its own (?)
- PowerShell joined Windows
  - Switched to the Windows build system
  - Would ship with Windows (Longhorn)
- LONGHORN RESET – WORLD EXPLODES
  - We were a .NET component so we were “kicked out” of Windows
- Crap. Now what do we do…

Shipping is Fun 2!

- Ok – drifting aimlessly – and along comes the Exchange team
  - They were investigating an automation solution for managing Exchange servers; especially GUI over command line.
  - PowerShell pretty much matched everything they were looking for. Yay – we have a new partner and a new shipping vehicle.
- Some impact on the product though
  - First, the shipping delay gave us a lot more time to refine what we had.
  - The focus was on Exchange features first. This meant that some things did not get as much attention as we would have liked
    - Native command support was weak in V1 (and still is to some extent).

Shipping Is Fun 3!

- Finally we get approval to ship as a *Windows* feature, not as Exchange feature
  - But first we have to pass some gates…
- Versioning requirement – you must never break anyone *ever ever ever*
  - Loose versioning == DLL hell. Rigid versioning is brittle and breaks; *worse is better*
  - Versioning is not a problem – problems can be solved. Versioning can't be solved, only mitigated. (`ICommandRuntime class`)
- No plugins requirement
  - At the time, plugins in IE were causing a lot of grief.
  - But PowerShell is all about plugins. So we had to do some work to meet this requirement.
    - First attempt – *minishells* – essentially requiring every module vendor to compile their own PowerShell executable: `powershell { invoke-code in new shell }`
    - Round 2 was Snap-Ins – patterned after MMC which was already shipping with Windows; included "console files" to preconfigure your environment

…`/src/System.Management.Automation/singleshell/config`

Shipping is Fun 4!

- Language reviews with the CLR & DLR teams
  - One of the big issues discussed was push vs pull
    - LINQ was being released; used a pull model
  - PowerShell used push (similar to the reactive framework (Rx))
  - Ultimately, this was resolved without much difficulty ☺
- Then someone noticed we could build software with PowerShell. *Rats!*
  - The msbuild development effort was a significant work effort in DevDiv
  - Through mechanisms unknown, somebody saw a slide talking about how PowerShell could be used as part of a software construction toolchain (just like sh/ksh/bash is used on UNIX).
    - Led to an unfortunate misunderstanding
    - Initially quite tense but it got cleared up reasonably quickly.

Shipping is Fun 5

- All clear to ship except for one little detail.
- Had to change the product name from “Monad” to “Windows PowerShell”.
  - Did a survery to justify name change
    - Which name sounds more powerful: Monad or PowerShell
    - Which name sounds more like a shell: Monad or PowerShell
  - Lots of code changes, setup changes, registry changes
- Most everything got cleared up but there are still traces in the code
  - e.g. PSObject is defined in the file `…/System.Management.Automation/engine/MshObject.cs`

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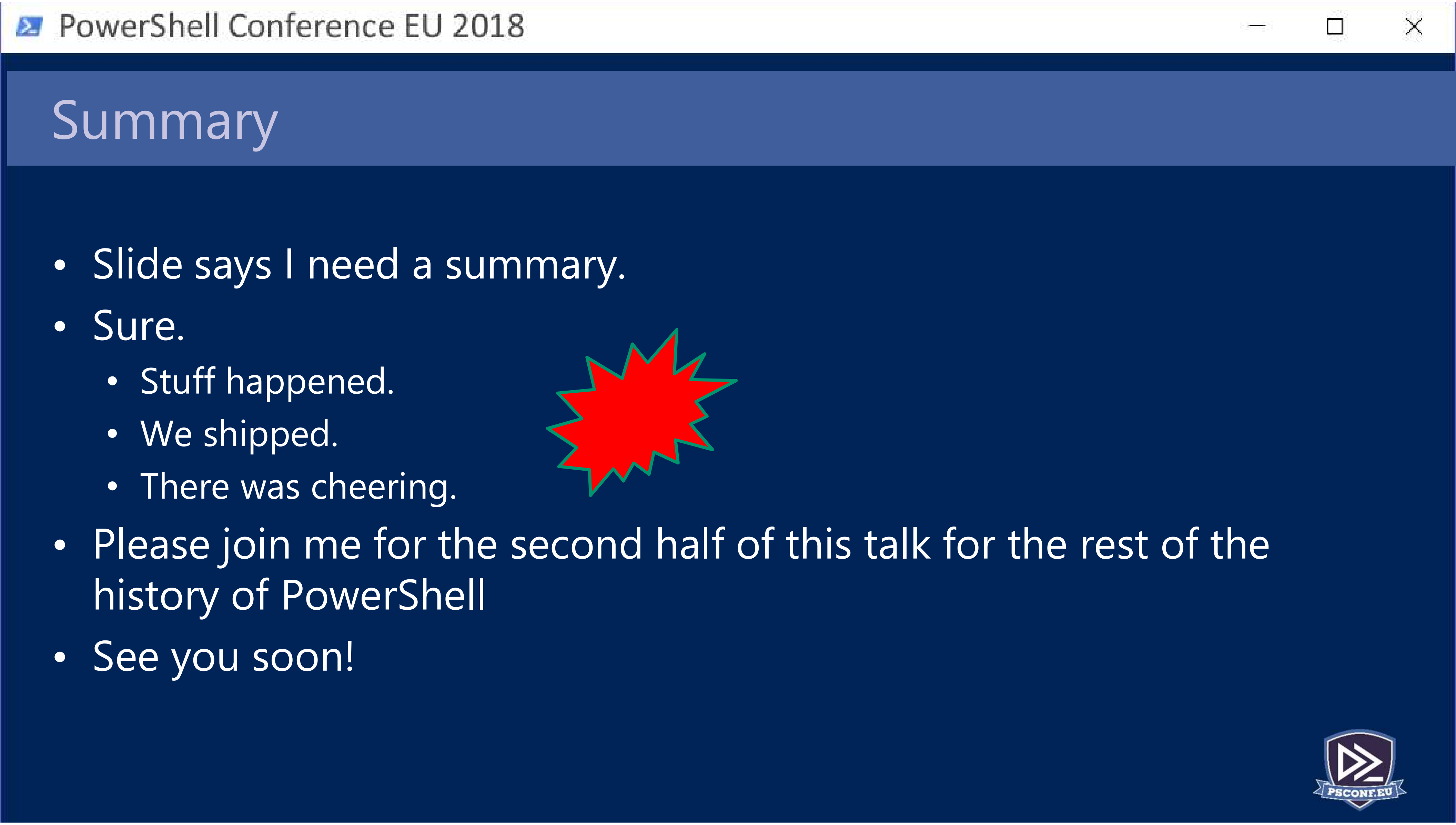
And We Shipped!

- PowerShell Version 1 shipped November 2006!



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Summary

- Slide says I need a summary.
- Sure.
  - Stuff happened.
  - We shipped.
  - There was cheering.
- Please join me for the second half of this talk for the rest of the history of PowerShell
- See you soon!

Next Steps

- Now: 15 min break

- Grab a coffee
- Stay here to enjoy next presentation
- Change track and switch to another room

- Ask me questions or meet me in a breakout session room afterwards

Questions?

```
# use this template for code samples
# and follow these instructions to show perfectly
# color-coded PowerShell code:

# paste code to PowerShell ISE, select it, and copy it
# to the clipboard
Paste-Code -ToISE | Select-Code | Copy-ToClipboard

# to insert it with full color-coding into a slide,
# paste the code to your PPT slide. It will be black,
# and there is a toolbutton labelled (Ctrl) in PPT.
Click-ToolButton -Choose SymbolWithClipboardAndBrush
# Click the toolbutton, and choose the button that shows
# a clipboard with a brush. This will add color-coding
# back to the pasted code
```

PLEASE NOTE: You do not need to use PowerShell ISE to code, or to demo. Use whatever editor you like best.

These steps use PowerShell ISE to color-code your code correctly and consistently, and insert the color-coded code into the slide. Please help make all code look consistent. Many thanks!

about_Author

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