# Wealth Optimization

## Risk, Return, Goals and Liquidity Through an Investors Lifecycle

**Dr. Dan Rosen**

**July 20th 2023**

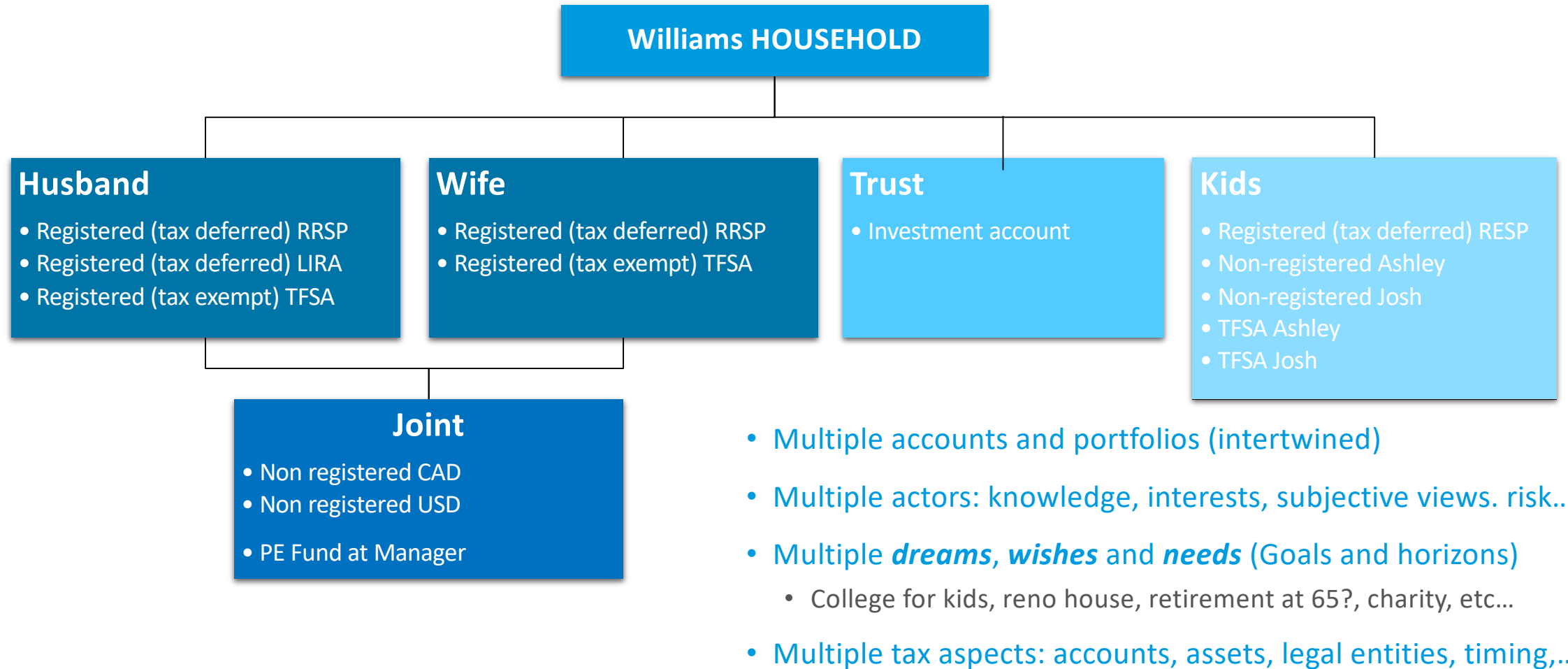# Optimization in Wealth Management

## *Creating Robots or Empowering Advisors?*

2

# It All Starts with a Client/Family

**d1g1t**

```
                          ┌─────────────────────────┐
                          │   Williams HOUSEHOLD    │
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```

**Husband**
- Registered (tax deferred) RRSP
- Registered (tax deferred) LIRA
- Registered (tax exempt) TFSA

**Wife**
- Registered (tax deferred) RRSP
- Registered (tax exempt) TFSA

**Trust**
- Investment account

**Kids**
- Registered (tax deferred) RESP
- Non-registered Ashley
- Non-registered Josh
- TFSA Ashley
- TFSA Josh

**Joint**
- Non registered CAD
- Non registered USD

- PE Fund at Manager

- Multiple accounts and portfolios (intertwined)

- Multiple actors: knowledge, interests, subjective views. risk…

- Multiple *dreams*, *wishes* and *needs* (Goals and horizons)
  - College for kids, reno house, retirement at 65?, charity, etc…

- Multiple tax aspects: accounts, assets, legal entities, timing,…

## The actual problem is very complex!

Financial Advisors work with ***people*** (individuals, families) with human goals, feeling, fears, and (*not so rational*) reactions… and in the real (complex financial) world

- Truly hard to define precisely the problem to optimize (goals, tolerance, trade-offs, reactions)

- Multiple stakeholders, goals, times, levels (utility)

- Constantly changing over time

- Very sensitive to changing individual life circumstances, unexpected life events, markets (ups-downs)

- The "subject/client" itself is changing as well: Individuals' tolerance, appetite and understanding of risk change constantly (education, experience, life events, a financial crisis,… )

- Model assumptions… over long horizons

- The advice itself may create an important feedback loop!

- Difficult to capture complete picture – optimization is very sensitive to these assumptions and  definitions

It's *all* about *Risk*...

# Adoption of Risk-Based Toolkit...

**Must be careful on borrowing from banking and institutional applications**

- For market risk, typically, short term

  - Banking: 1 day (trading)  or 1-2 weeks (regulation)

  - Asset Management: longer, e.g. 1 month

- Used for controls/limits, trading, hedging, optimization

- Objective related to maximize risk adjusted returns
  (perhaps relative to a benchmark
  for Asset Management)

**For wealth management... this is different...**

**2015+**
**Wealth Management**
- Goal-based investment
  & portfolio management
- Risk & performance
- Communications: advisors
  & individual investors

**2000s**
**Buy Side**
- Asset managers
  & hedge funds
- Risk & portfolio
  analytics, trading
  strategies

**1990s**
**Banks**
- Risk management
  & trading platforms
- Banking regulation

# It's all About Risk... ... but Risk is Not a Number....

## Risk in wealth management involves more than just analyzing a portfolio

- Entire view of a family's wealth... not only a single investment portfolio

- Multiple portfolios and accounts... and tax implications...

- A client's (family's) risk capacity/tolerance/appetite

- Multiple goals and timelines... over long horizons (5, 10, 20, 50 years)

  - Accumulation (pre-retirement) and decumulation (post-retirement) periods


- Scale... if you are a successful advisor, you likely have a large number of clients that you want to manage efficiently...

# It's *all* about Risk… … but Risk is Not a Number….



**In financial advice…** **Risk is a "Story"**

*A powerful communication tool constantly guiding the narrative and the engagement*

# The Wealth Management Risk Cycle



**Risk Policy**
*Investment Mandates, IPS, Accounts*

**Required Risk Consumption**
*Personalized Goals & Financial Plan*

**Risk Taking**
*Investment Portfolios, Construction & Rebalancing*

**Wealth Analytics**

**Clients**

**Portfolios**

**Risk Appetite & Capacity**
*Onboarding & KYC*

**Risk Monitoring & Management**
*Performance, Exposures, Risk & Stress Scenarios*

**Business**

# Investor's Risk Profile

**Multiple metrics are needed to characterize an "Investor's Risk"**

- Risk Capacity

- Risk Tolerance / Risk Appetite

- Financial knowledge

- Information appetite

**Risk return trade-off / risk aversion**

**Tools include: Behavioural Finance and Psychometrics**

# Investor's Risk Profile
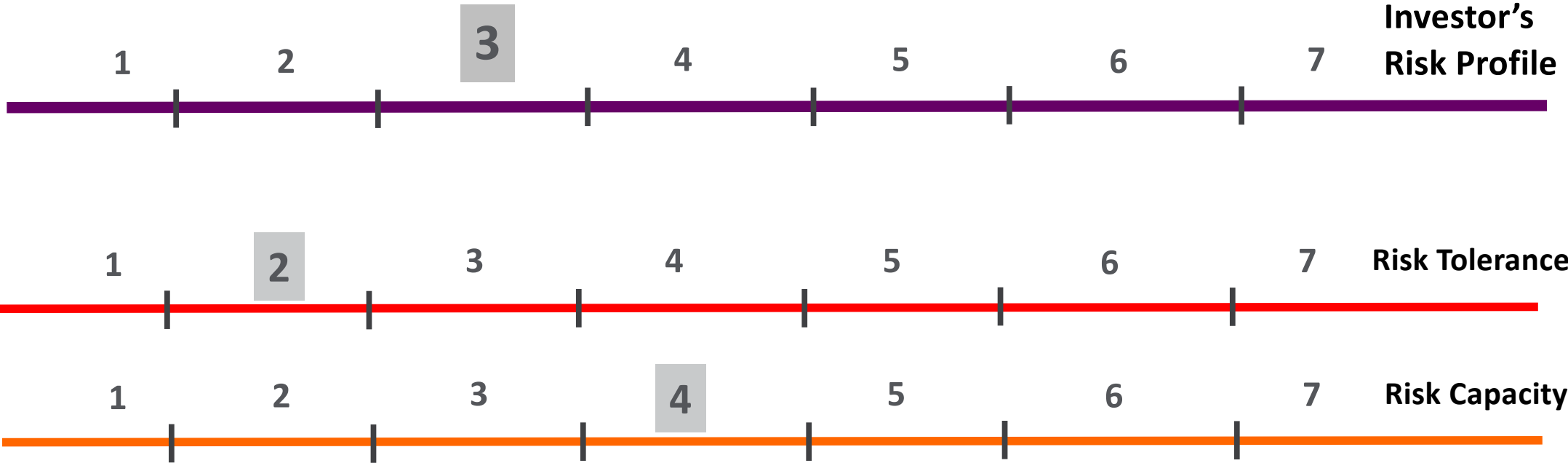


**Household/Family: risks profiles defined for the entire household and members**

# Aligning Risks across the Cycle



Investor's Risk Profile

| 1 | 2 | **3** | 4 | 5 | 6 | 7 |

Portfolio Risk Mapping

Very Conservative    Income    Balanced    Growth    Aggressive

3.3 %

2 %    4 %    6 %    10 %
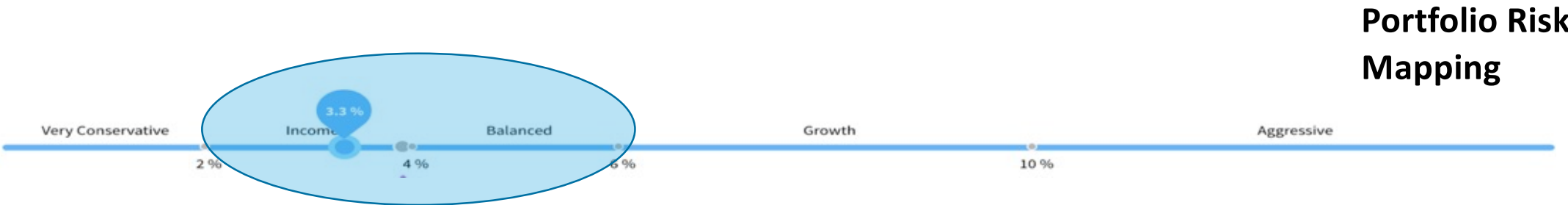
# Goals & Risk

Goals reflect an investor's (individual or household) needs, wants, wishes and dreams

Typical measures for future short-term portfolios (large) losses do not relate directly to goals

- VaR, expected shortfall, volatility, drawdown…

Goal-based Risk → the possibility of not achieving these goal(s) in the future, how far we will be, and the severity/consequences (for a given portfolio or investment strategy over time)

Relevant metrics

- Probability of meeting goal(s)

- Distance to meet goal (for a given strategy and scenarios)

- Expected shortfall (conditional on not meeting goal)

- Trade-offs between competing goals

# Long-Term Wealth Simulation (Accumulation)

**d1g1t**

**Projected Wealth Simulation**

At **65** years old, you expect to have accumulated **$6,725,456**

Goal: Retire at 65
- $200,000/year until age 95
- High likelihood of achieving (90%)

Goal: $7,050,186

**Year 2026**
- Goal: $7,050,186
- Expected: $6,951,465
- 50% probability of having between $6,530,357 and $7,345,222
- 10% probability of having more than $7,759,369
- 10% probability of having less than $6,187,001

8M
7.5M
7M
6.5M
6M
5.5M
5M
4.5M

2020
(57 YRS)

2025
(62 YRS)

20
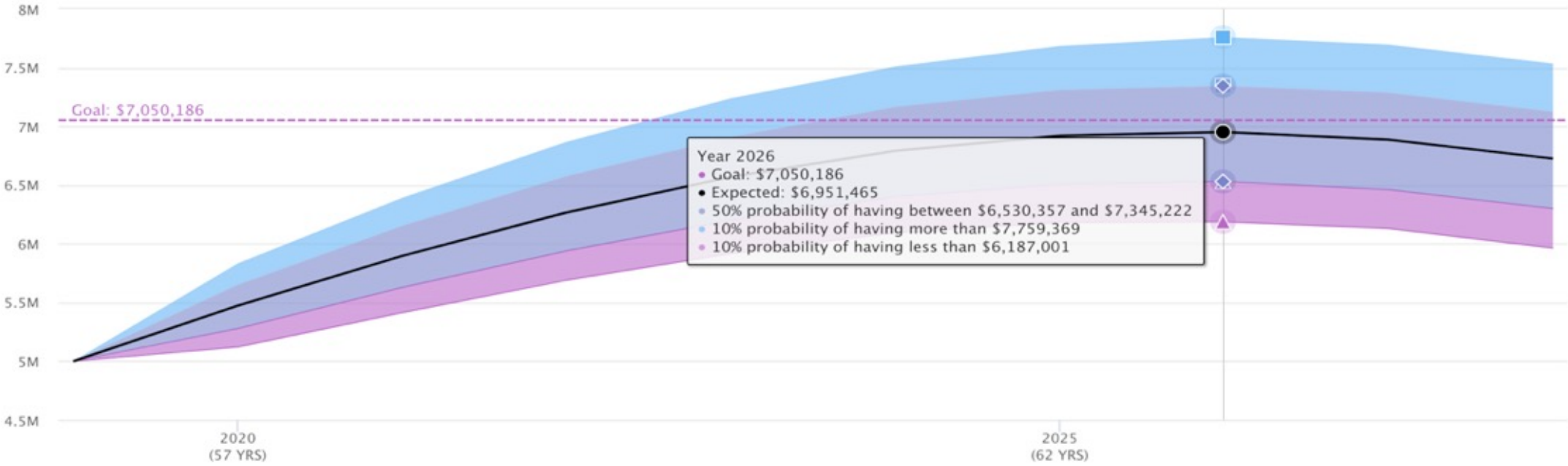
# Long-Term Wealth Simulation (Retirement Income & Decumulation)



Projected Wealth Simulation

Year 2028
- Goal: $7,050,186
- Expected: $7,639,966
- 50% probability of having between $7,257,849 and $8,002,625
- 10% probability of having more than $8,341,389
- 10% probability of having less than $6,956,269

Goal: $7,050,186

☑ Show decumulation period

How is this calculated?
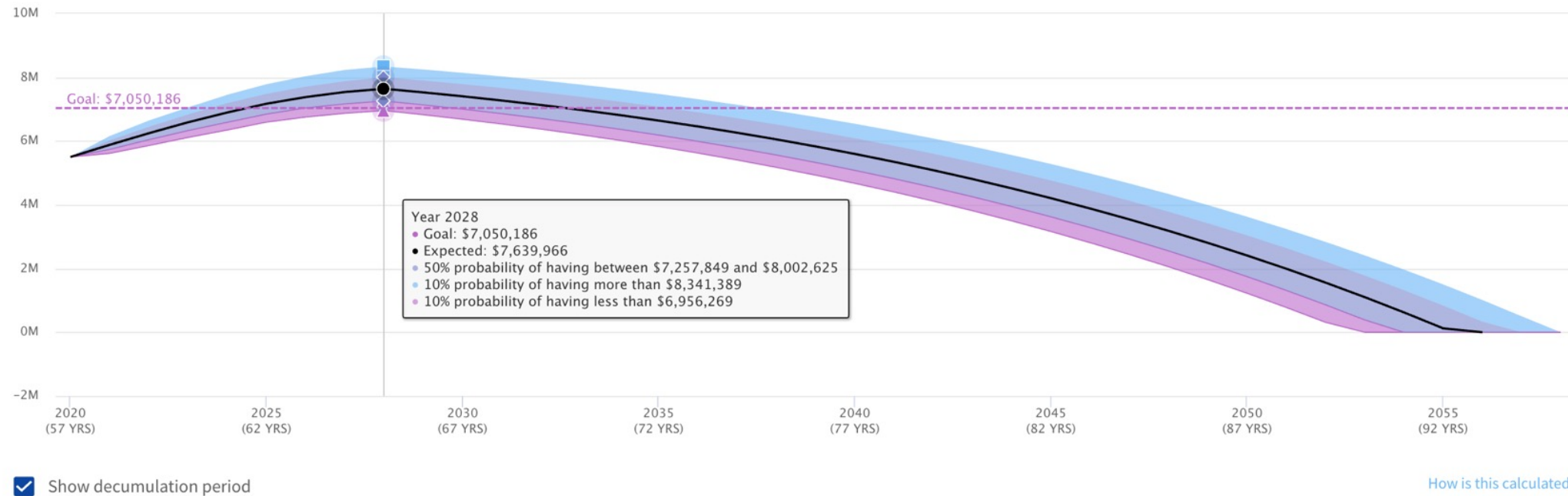
# Investment Plans, Mandates, IPSs

## In practice, this needs to be realistic

- Multiple goals and timelines

- Multiple actors: different risk profiles and timelines

- Multiple sources of funding (different rules, taxes)

## Solution must be actionable: easy to execute, track, and communicate

- Multiple mandates/sub-mandates acting together

- Funded through multiple accounts and financial vehicles (e.g. trusts and insurance)

# Constructing & Rebalancing Portfolios

**IPS – Model Portfolio's Risk**

| Very Conservative | Income | Balanced | Growth | Aggressive |
|---|---|---|---|---|
| 2 % | 4 % | 6 % | 10 % | |

3.3 %

3.9 % required

**Actual Portfolio's Risk**

| Very Conservative | Income | Balanced | Growth | Aggressive |
|---|---|---|---|---|
| 2 % | 4 % | 6 % | 10 % | |

3.3 %

3.9 % required

Total Return ▾  for  3 Years ▾

Risk Return Map ▾  3 Years ▾

— Jay Pritchett  — Growth Model
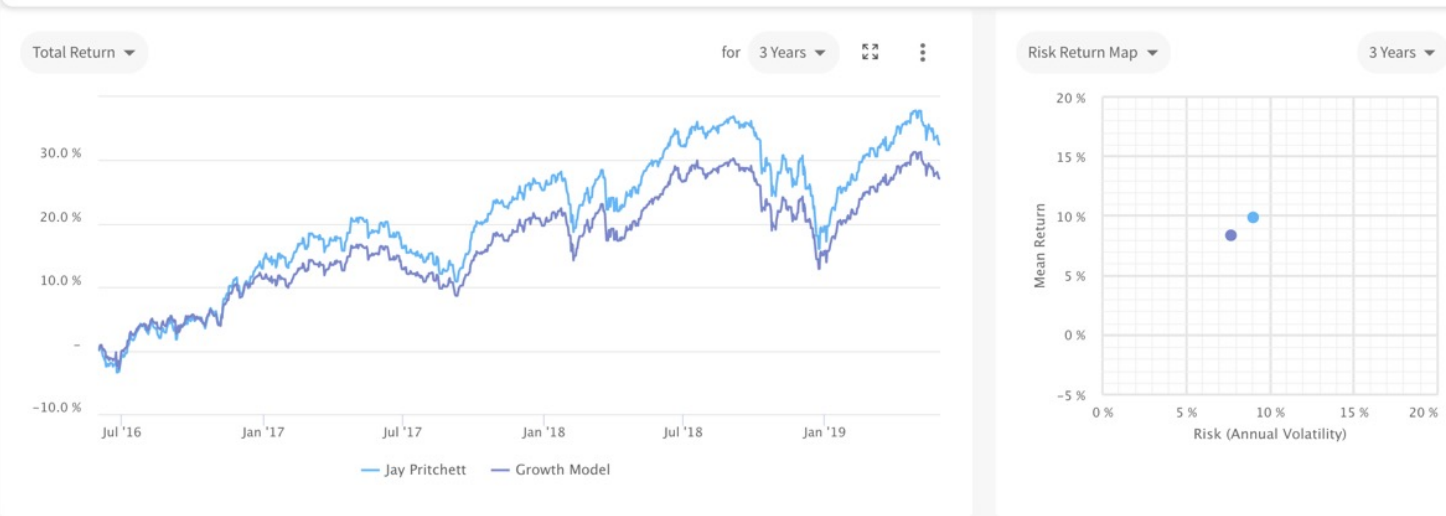
Search for data containing...  Portfolio View ▾

| Security Name | Return (YtD) | Return (1Y) | Return (3Y) | Volatility (3Y) | VaR (90%) | Drawdown (3Y) | % of Portfolio Total | Cash & Cash Equivalent | Equity | Fixed Income |
|---|---|---|---|---|---|---|---|---|---|---|
| Jay Pritchett | 10.9 % | 2.3 % | 9.6 % | 9.9 % | 5.2 % | 13.6 % | 100.0 % | 8.8 % | 90.0 % | 1.2 % |
| Growth Model | 10.0 % | 2.5 % | 8.4 % | 8.6 % | 4.4 % | 12.0 % | 100.0 % | 2.8 % | 77.1 % | 20.1 % |

# Aligning Risks across the Cycle – Tracking Mandates & Portfolios



**Investor's Risk Profile**

1    2    **3**    4    5    6    7

**Portfolio Risk Mapping**

Very Conservative    Income    Balanced    Growth    Aggressive
2 %    4 %    6 %    10 %
3.3 %

**Goal Based Risk**
(required consumption)

Very Conservative    Income    Balanced    Growth    Aggressive
2 %    4 %    6 %    10 %
5.6 %
3.8 % required

**Model Portfolio's Risk**

Very Conservative    Income    Balanced    Growth    Aggressive
2 %    4 %    6 %    10 %
3.3 %
3.9 % required

**Actual Portfolio's Risk**

Very Conservative    Income    Balanced    Growth    Aggressive
2 %    4 %    6 %    10 %
3.3 %
3.9 % required

30

# Risk Monitoring – Investment Light Cone Analytics

# Monitoring Portfolios: Exposures, Performance, Risk
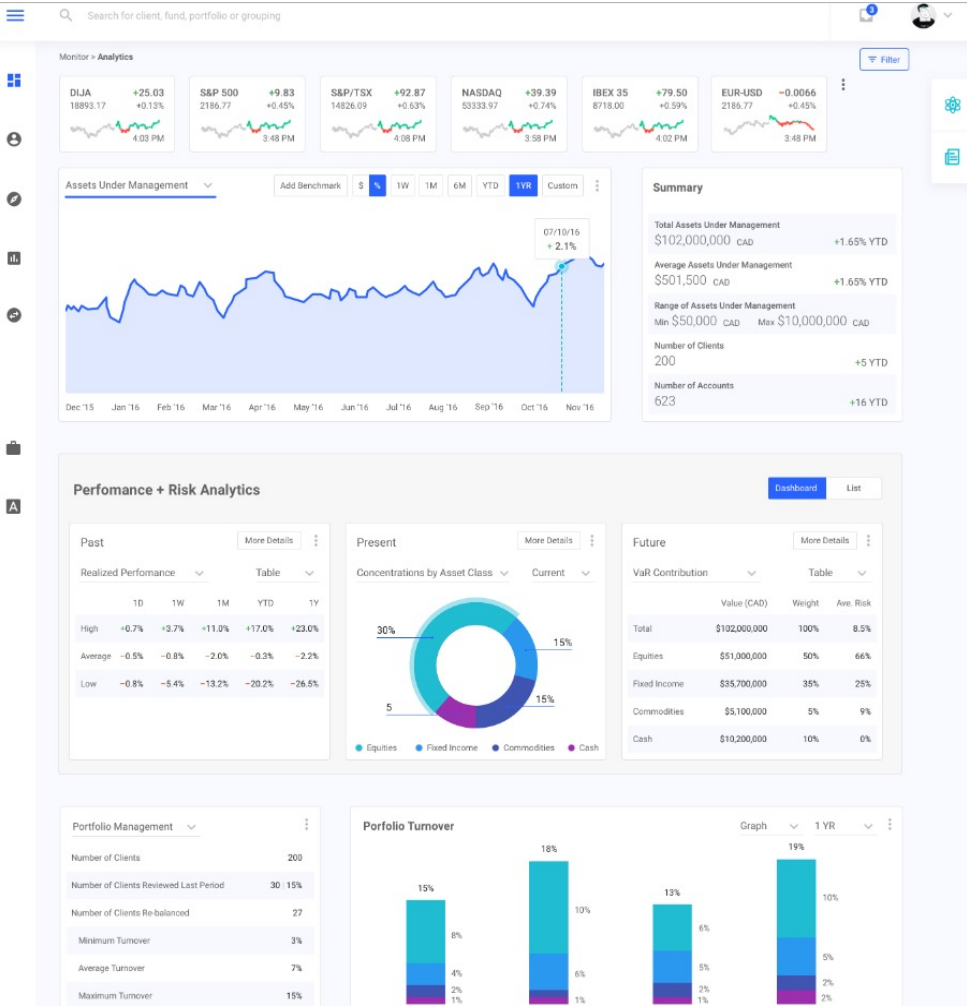


**Tracking Portfolios...
and _understanding causes_:**

- Exposures: slice & dice

- Performance attribution

- Risk contributions

- Scenario Analysis

- Risk factor analysis and decomposition

- Cashflow forecasts

# The Wealth Management Risk Cycle



**Risk Policy**
*Investment Mandates, IPS, Accounts*

**Required Risk Consumption**
*Personalized Goals & Financial Plan*

**Risk Taking**
*Investment Portfolios, Construction & Rebalancing*

**Risk Appetite & Capacity**
*Onboarding & KYC*

**Risk Monitoring & Management**
*Performance, Exposures, Risk & Stress Scenarios*

**Analytics**

**Manage Clients**

**Manage Portfolios**

**Manage the Business**

**Enterprise Risk Management**

# Wealth Management Risk... and Performance

**Behavioural**

- Risk Tolerance
- Risk Capacity
- Risk Appetite

**Clients**

**RISK**

**Goals**

**Portfolios**

- **Exposures**
- **Performance attribution**
- **Portfolio Risk & diversification**
  - Market Risk (short & long-horizon)
  - Credit Risk
  - Liquidity Risk
- **Stress Scenarios**

**ALM/Household Treasury**

- Gap Risk
- Shortfall
- Prob of achieving goal (distance to Goal)

# Wealth Portfolio Optimization: Efficient Portfolio Manufacturing at Scale!

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**Manage the Business**

**Enterprise Risk Management**

Objective: provide personalized, and high-touch portfolio investment programs for 100s or 1000s of clients in an efficient manner

- Understand the entire book of business

  - Pro-actively (instead of reactively) address which clients

    - Require more attention

    - Can take advantage of an opportunity

    - Are more affected by a given market event…

- Dynamic, interactive engagement with a given client to define what is important and understand trade-offs

# The Mother-of-All Portfolio Optimization in Wealth Management
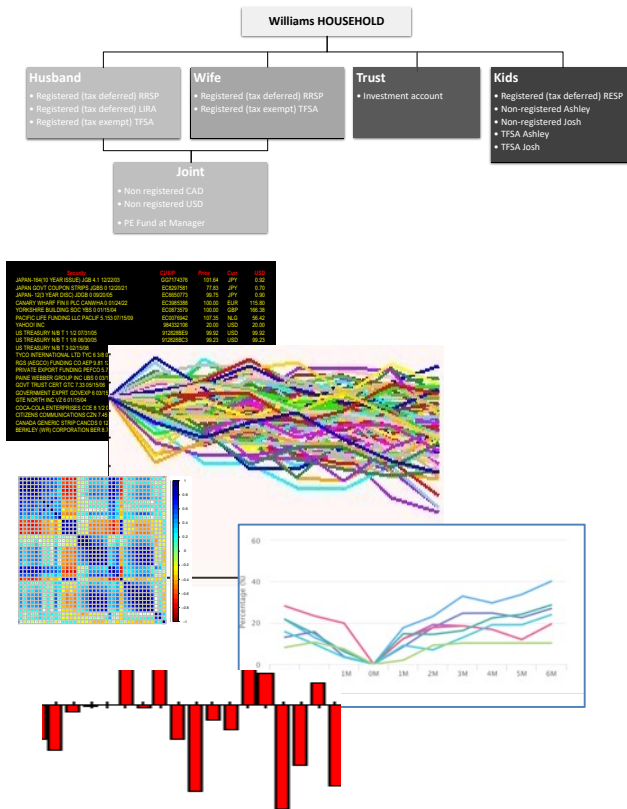


## Find the "Optimal" overall portfolio strategy for the Household

- Maximizes multi-criteria utility function
  - Multiple goals over time: inflows and outflows; some terminal wealth (or multiple) on a long horizon
  - Accounting for taxes, risk profiles, stochastic markets
  - Rich scenario set (multi-factor forecasting model)
  - Takes best advantage of investment universe available
  - Complex constraints: consistent with multiple client risk/investment preferences, liquidity, compliance/regulatory (tax)

## Output

- Asset (risk-factor) allocation now
  - Across all members (legal-entities) and accounts (location)
- Dynamic allocation over time (long horizon)

# Quantitative Portfolio Manufacturing Process

**1. Product Manufacturing**
*Efficient Portfolios/ Model Portfolios*

**5. Risk Monitoring & Management**
*Performance Attribution, Exposures, Risk & Stress Scenarios*

## Wealth Optimization

**2. Product Customization**
*Personalized, Client Specific Portfolios*

**4. Tax efficiency**
*Account Location, Tax Harvesting, etc…*

**3. Dynamic Risk Allocation**
*Consumption & Funding: Goals, Liquidity Management*
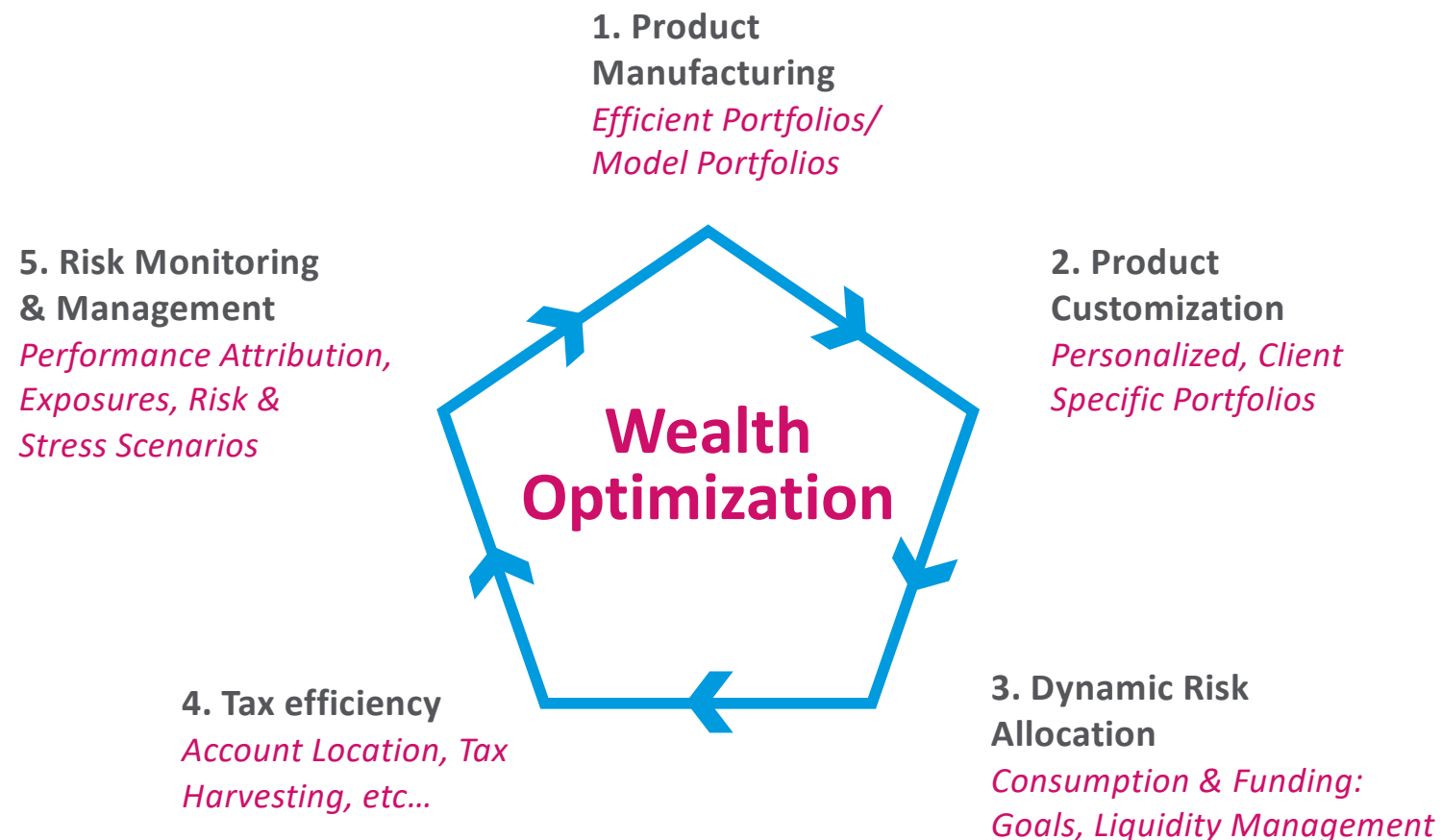
Goal: to use the best financial optimization tools to break the process into a set of steps:

*Effective*,

*Manageable*,

*Repeatable*,

and *Scalable*.

# Quantitative Portfolio Manufacturing Process

**1. Product Manufacturing**
*Efficient Portfolios/ Model Portfolios*

**Wealth Optimization**

## Efficient Portfolios & Model Portfolios

Construct set of optimal model portfolios or investment programs, based on available investment vehicles and expertise (available for all clients... segmented)

- Define *Investment Universe* (opportunities)
- Asset allocation, risk factor allocation, diversification
- Advanced optimization toolkit: e.g. Black-Litterman, Bayesian models, etc...

Output: full set(s) of "efficient" **general Model Portfolios**

### Investment Universe

# Quantitative Portfolio Manufacturing Process

**1. Product Manufacturing**
*Efficient Portfolios/ Model Portfolios*

**Wealth Optimization**

**2. Product Customization**
*Personalized, Client Specific Portfolios*

## Customized Client Model Portfolios

Adjust model portfolios to create a specific personalized subset for each individual client

- Additional Input: client specific constraints, investment preferences

- Use of advanced optimization toolkit for asset/risk factor allocation, diversification

- Output: subset of adjusted **client-specific "efficient" Model Portfolios**

**Client Specific Model Portfolios**

# Quantitative Portfolio Manufacturing Process

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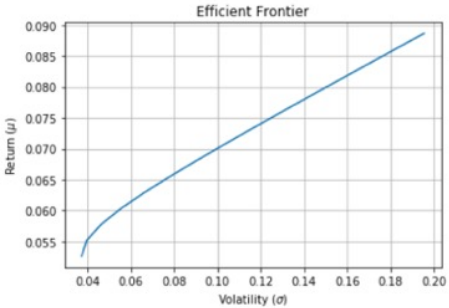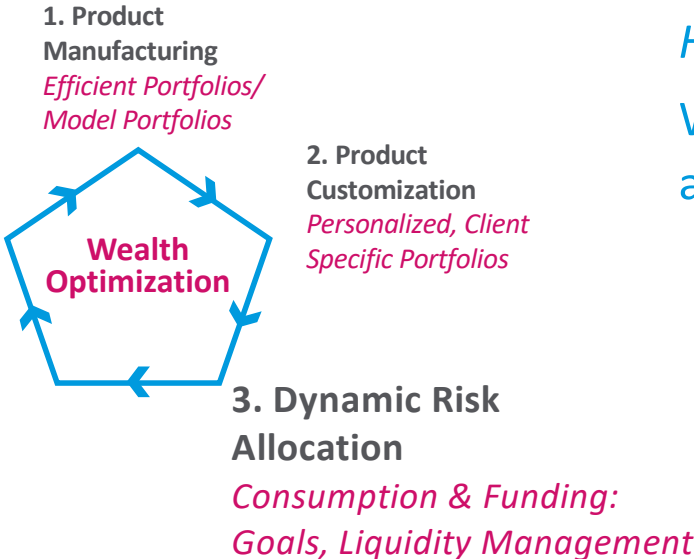
*How do we pick how many portfolios and "Lambdas"?*

Which portfolios or asset/risk factor allocations do we invest in now… and over time (rebalancing)



Efficient Frontier

# Quantitative Portfolio Manufacturing Process

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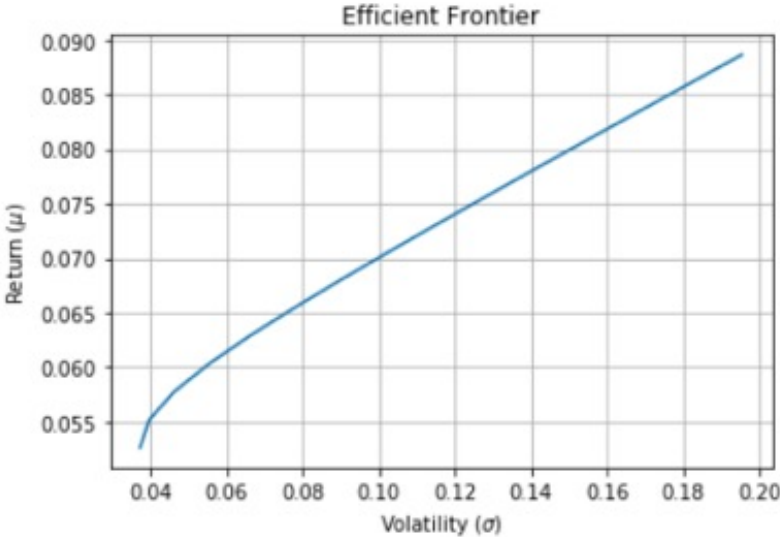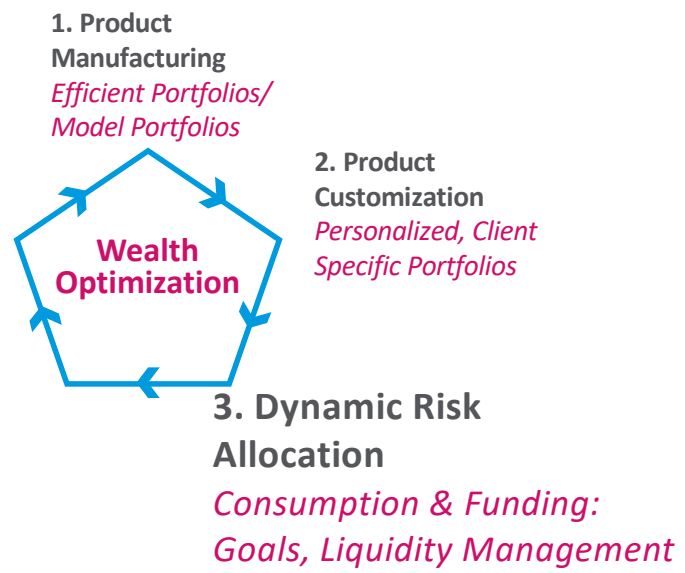
Dynamic Portfolio Investment Strategies: meet goals and manage liquidity (long horizons, 10-50 years)

Goal-based Wealth Management (*Household ALM*)

- Includes accumulation, liquidity management (inflows, outflows, capital calls, etc...) and decumulation/wealth transition (post retirement)

- **Stochastic Dynamic Portfolio Optimization**: dynamic programing and machine learning tools (Reinforcement Learning, Neural Networks)

Output: **dynamic allocation** (of efficient portfolios) of over time based on goals, sensitivities and what-if analysis

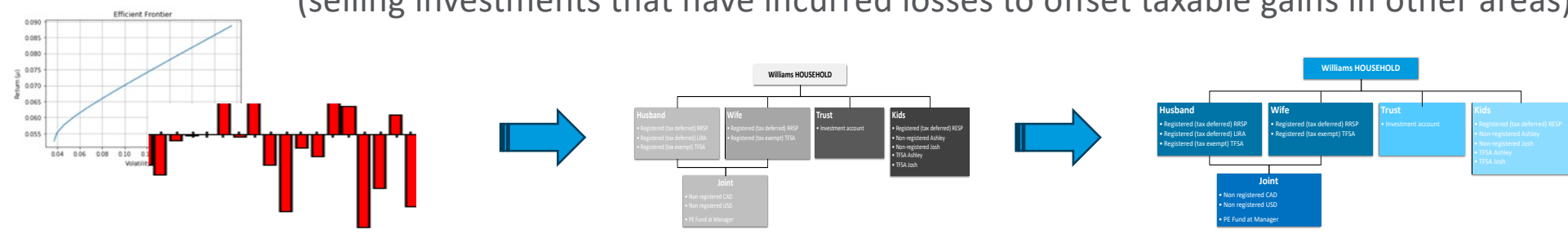# Quantitative Portfolio Manufacturing Process

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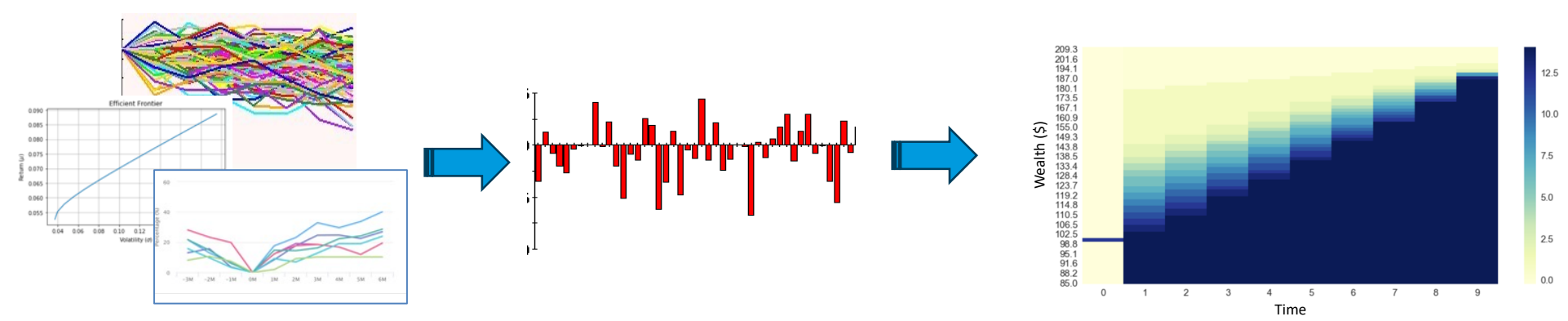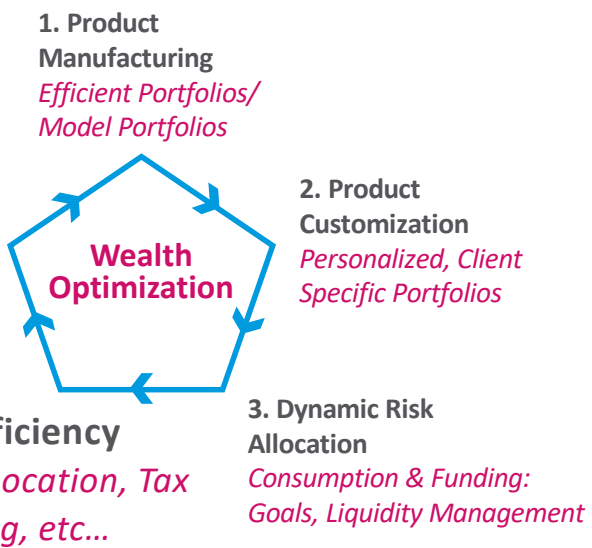
## Optimize for Tax Efficiency (*maximize after-tax risk-adjusted returns*)

Detailed tax optimization to adjust portfolio location and sources of income streams

- Account for: different tax-advantaged accounts, marginal tax rates for different products, income sources, and legal entities, the timing of realized gains)

- Optimization model incorporates details on:

  - Income thresholds, tax brackets, deduction limitations, specific rules related to tax-advantaged accounts, tax lots, etc..

  - Tax Rate Functions applicable to different income levels and types of income (e.g., ordinary income vs. capital gains)

Output: client and account location, income adjusted plan, tactical tax harvesting (selling investments that have incurred losses to offset taxable gains in other areas).

# Quantitative Portfolio Manufacturing Process



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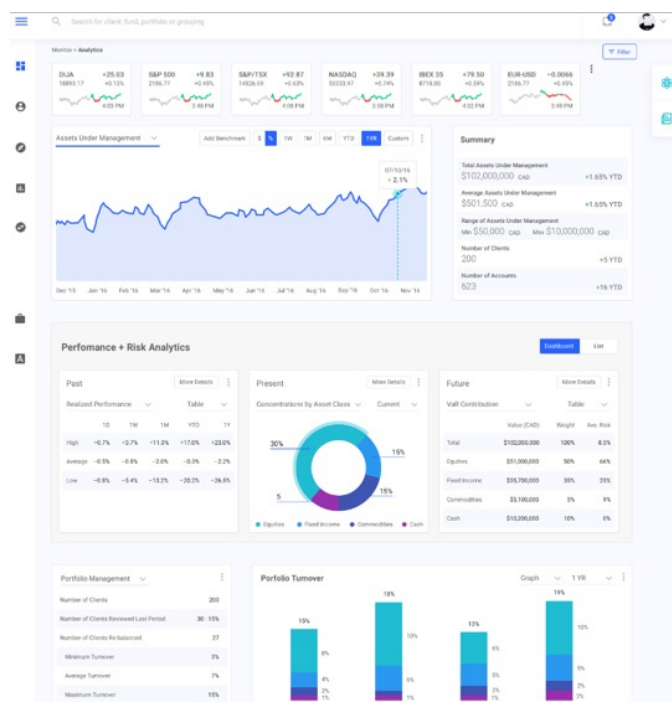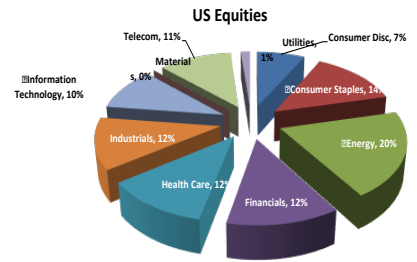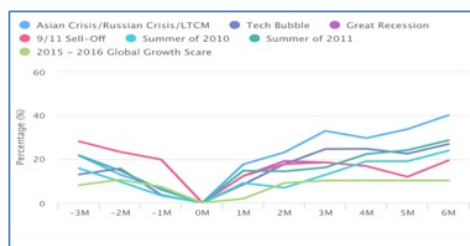
**Wealth Optimization**
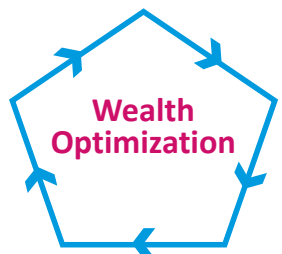
**2. Product Customization**
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**3. Dynamic Risk Allocation**
*Consumption & Funding: Goals, Liquidity Management*

## Actively Monitor and Understand Exposures, Performance and Risk

- Compliance with IPSs and client periodic reviews
- Changes in: markets, client's life circumstances, goals, regulation, …
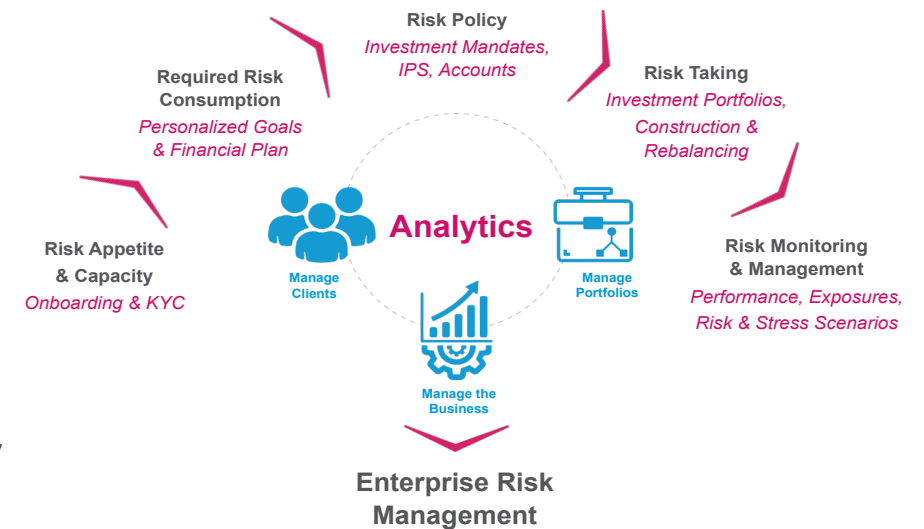- What if – available new funds or investment opportunities
- Scenario analysis

# Analytics Across The Wealth Management Risk Cycle

## The modern Wealth Management analytics toolkit integrates

- Behavioural Finance

- Goal-Based Planning

- Modern Portfolio Theory, Portfolio Optimization

- Risk Measurement/Management Tools

- Data science, marketing

Analytics

- OR tools: decision making and planning under uncertainty

- AI / Machine Learning

- Computational Finance and economics



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## *... Specifically: a long-term investment focus*

# Example: Goal-Based Wealth Management

**Goals-based wealth management** (**GBWM**):

Management of an investor's portfolios

with a view to meeting long-term financial goals
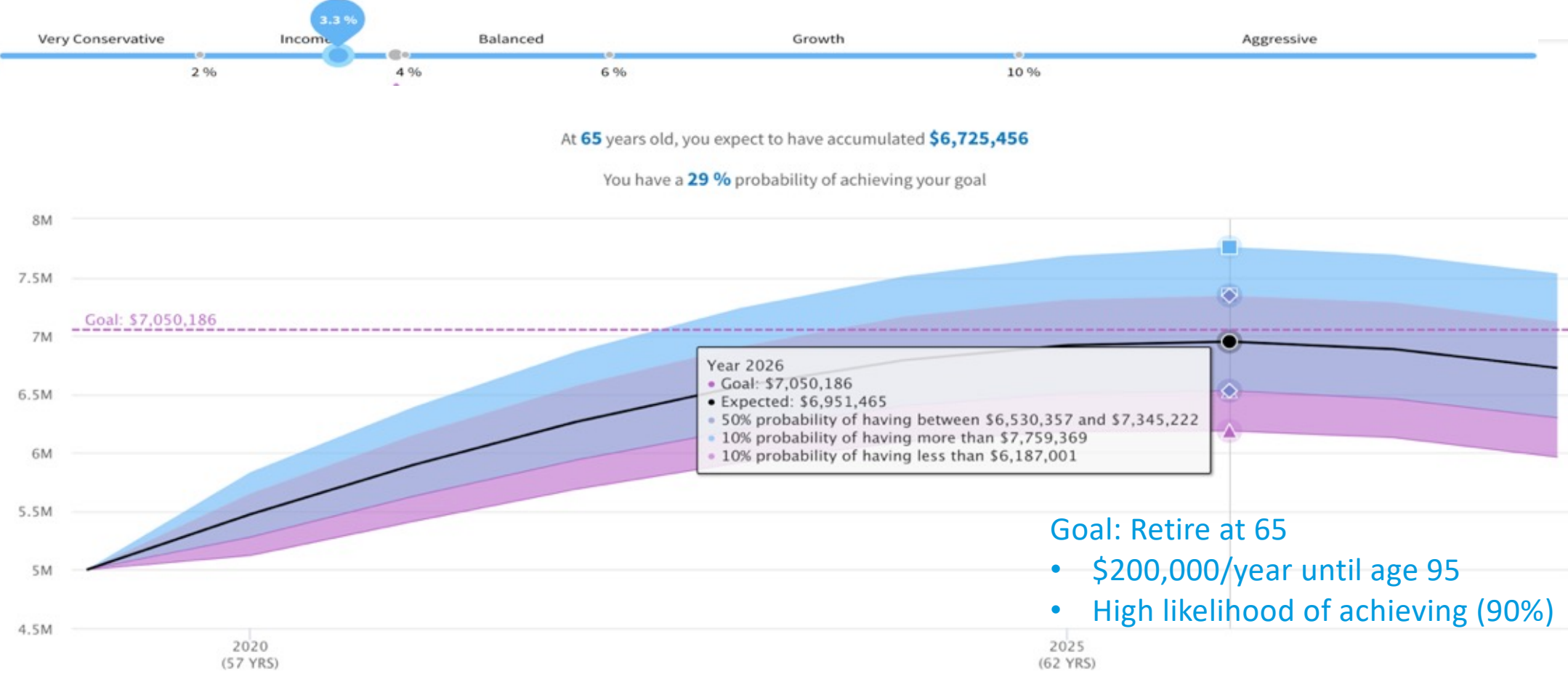
(as opposed to only optimizing a risk-return tradeoff)
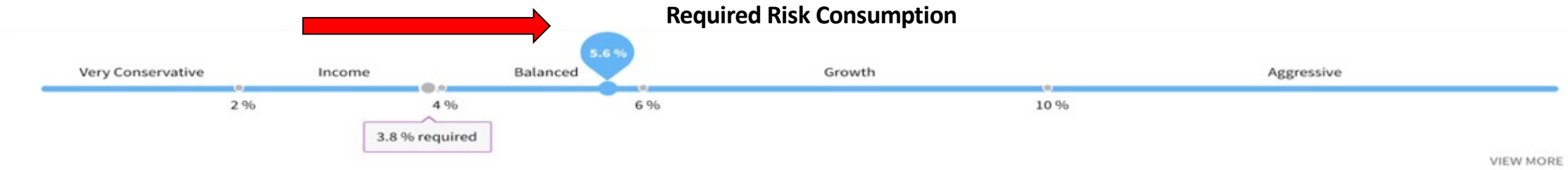
In the end:
Why are we saving money? … to invest it.
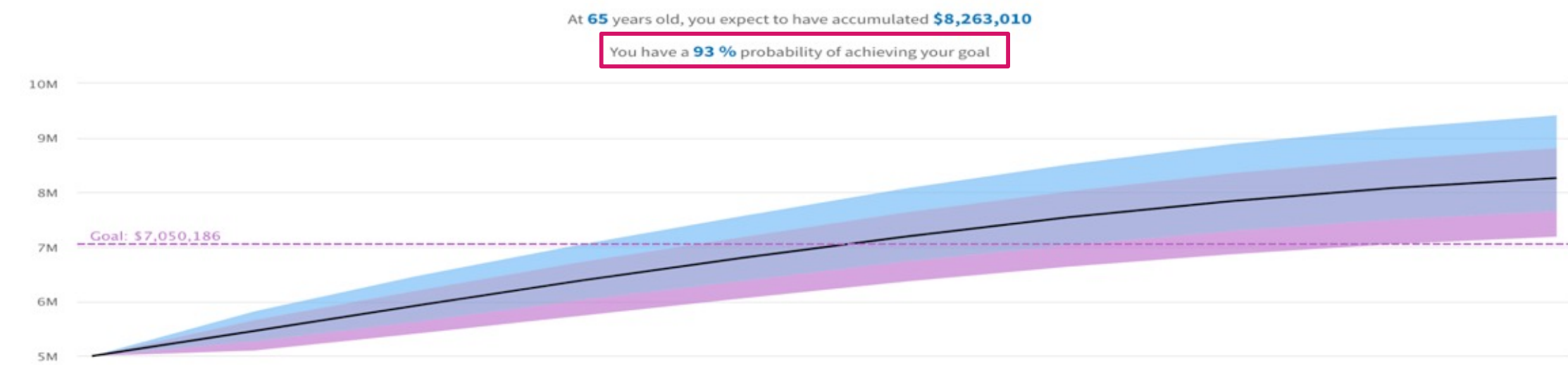Why are we investing? … to fulfill some important goals in the future

# GBWM – Wealth Simulation

# GBWM- Wealth Simulation

**Required Risk Consumption**

Very Conservative     Income     Balanced     5.6 %     Growth     Aggressive

2 %     4 %     6 %     10 %

3.8 % required

VIEW MORE

**Projected Wealth Simulation**

At **65** years old, you expect to have accumulated **$8,263,010**

You have a **93 %** probability of achieving your goal

10M

9M

8M

7M    Goal: $7,050,186

6M

5M

# Integrating GBWM, MPT & Risk



- **We can consistently combine:**
  - Goal Based investment planning
  - Modern Portfolio Theory, Portfolio Optimization tools
  - Psychometrics and behavioural finance

- **Focus on (long-term) risk measures related to:**
  - Probability of achieving goal(s)
  - Distance (shortfall) to achieving goal(s)

- **Create explicit links to portfolio risk measures (volatility, VaR, drawdown, etc…)**

- **Optimal solution: portfolio(s) to choose now…. + the strategy over time**

# Integrating GBWM, MPT & Risk



**Risk Taking**

**(Strategies, Portfolios)**
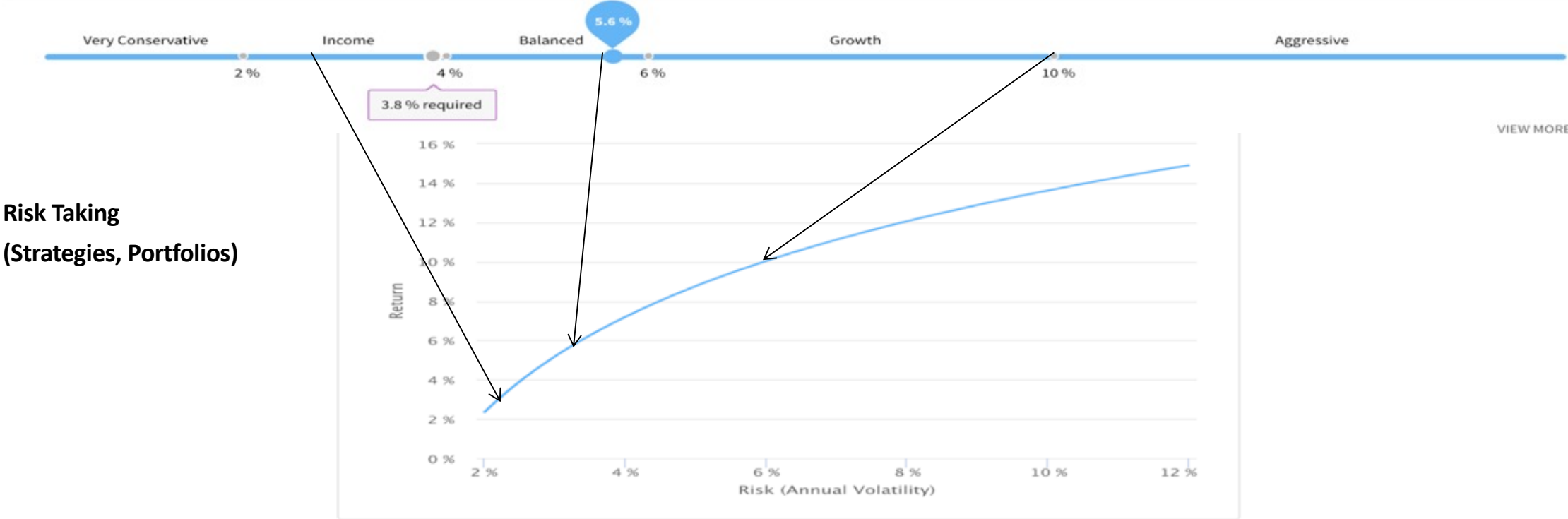
# Integrating GBWM, MPT & Risk
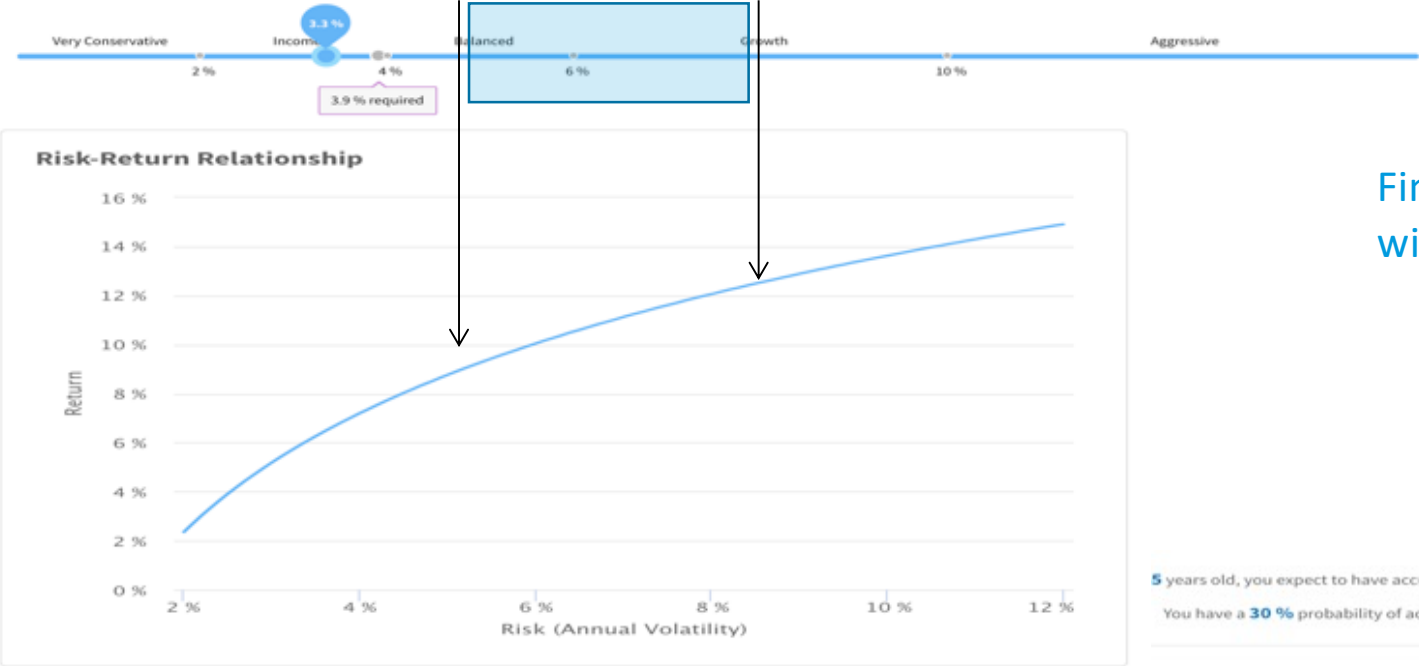


Find Portfolios that achieve goal with at least 90% probability

# Goal-Based Portfolio Optimization

Goal Based Portfolio Optimization – intuitive and actionable tool for financial advisors

- Maximize the likelihood of achieving the goal (or set of goals)

- Minimize the distance to achieving the goal (e.g. mean squared errors, shortfall)

Key insight: integrate MPT by choosing the portfolio set on the efficient frontier – splitting:

- Optimal asset allocation, and

- Required risk taking to achieve goal

**Example – Das et al.** (Markowitz Price, JoIM 2019)

- Static (constant risk) solution

- Dynamic goal-based portfolios (using stochastic dynamic programming)

- Trading off Multiple goals

- Dynamic portfolios via Reinforcement Learning

Other examples: Dixon & Halperin (Quants of the year 2022), Forsyth et al….

# Dynamic Portfolio Optimization for GBWM

## The static case is easy to understand and solve – but not "dynamically" optimal

- Implementations in practice are done period by period, in a simplistic manner

- Widespread rule-of-thumb approaches, such as "target-date" portfolios

## Dynamic programing solutions outperform static solutions and rules-of-thumb

- Discrete-time dynamic programming approach

  - Fast and simple to implement

  - Flexible: handle periodic infusions/withdrawals, bankruptcy, multiple goals at different times

  - Insights into real-life implementation strategy, effects of changing environment over time

- More general Machine Learning tools (RL and NN)

## Remember… Key insight: splitting

- Optimal asset allocation, and

- Required dynamic risk taking over time to achieve goal

# Dynamic Portfolio Optimization for GBWM – Key Features

1. Objective Function

   - The standard dynamic programing approach: ***Max Expected Utility*** (consumption over time & final wealth)



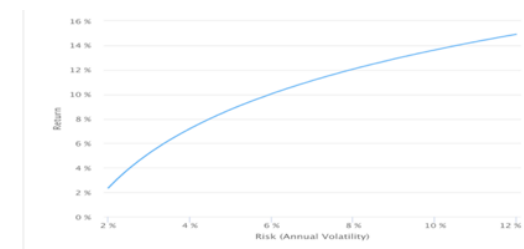   In GBWM, we can alternatively use more intuitive objective functions (e.g. Das et al, Forsyth et al):

   - Maximize Probability of achieving the goal:

        ***max Pr {W(T) > G}***

   - Minimize the Distance to achieving the goal (or to underperforming goal):

        ***min E { ||W(T) – G || _}*** (typically the 2-norm)

# Dynamic Portfolio Optimization for GBWM – Key Features

1. Objective Function (e.g. Das et al, Forsyth et al)

   - Maximize probability of achieving the goal: *max Pr {W(T) > G}*

   - Minimize the Distance to achieving the goal (or to underperforming goal): *min E { ||W(T) – G || _}*

2. Decisions, *A(t)*: *allocations* from a finite set of possible portfolios available at each *t = 0, 1, 2, . . . , T – 1*

   - Most people solve directly the full asset allocation (*n* asset classes or large-*n* instruments) at every step

     - This can be a difficult, multi-dimensional problem

   - Instead, decision variables *A(t)* are discretized into a finite sub-set

     - Computationally efficient

     - Consistent with advisor-investor problem, portfolios can be chosen from a set of available *Model Portfolios*

3. Efficient portfolios: Portfolios *A(t)* in the efficient frontier – consistent with MPT

# Dynamic Portfolio Optimization for GBWM – Key Features

1. Objective Function (e.g. Das et al, Forsyth et al)

    - Maximize probability of achieving the goal: *max Pr {W(T) > G}*

    - Minimize the "Distance" to achieving goal (or to underperforming goal): *min E { ||W(T) − G || _}*

2. Decisions, *A(t): allocations* from a finite set of possible portfolios available at each *t = 0, 1, 2, . . . , T − 1*

    - Decision variables are discretized into a finite sub-set (not solving directly full asset allocation for every step)

3. Efficient portfolios: typically, the portfolios *A(t)* are in the efficient frontier – consistent with MPT

4. Solution: function over the 2-D discretized grid in *t  and  W(t)*

    - **Dynamic programming** (backward recursion): most effective when wealth process *W(t)* is tractable (e.g. GBM), as we need to calculate conditional probabilities

    - **Reinforcement learning** (RL) or **Neural Networks**: applicable to a general setting and non-parametric, data-driven, processes (e.g. Das et al, Forsyth et. Al, Halperin et al)
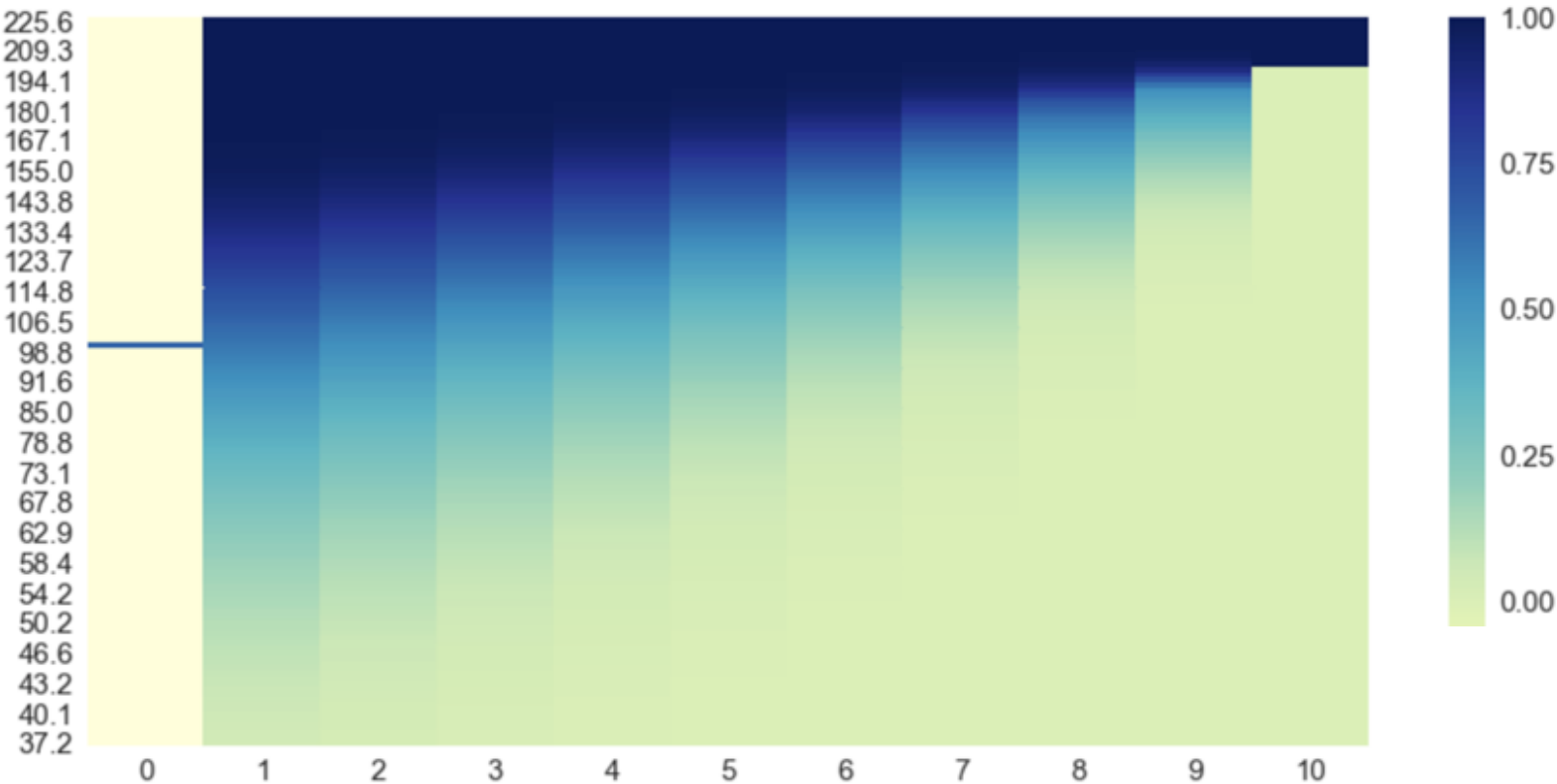
# Dynamic Portfolio Optimization – Example (Das et al.)
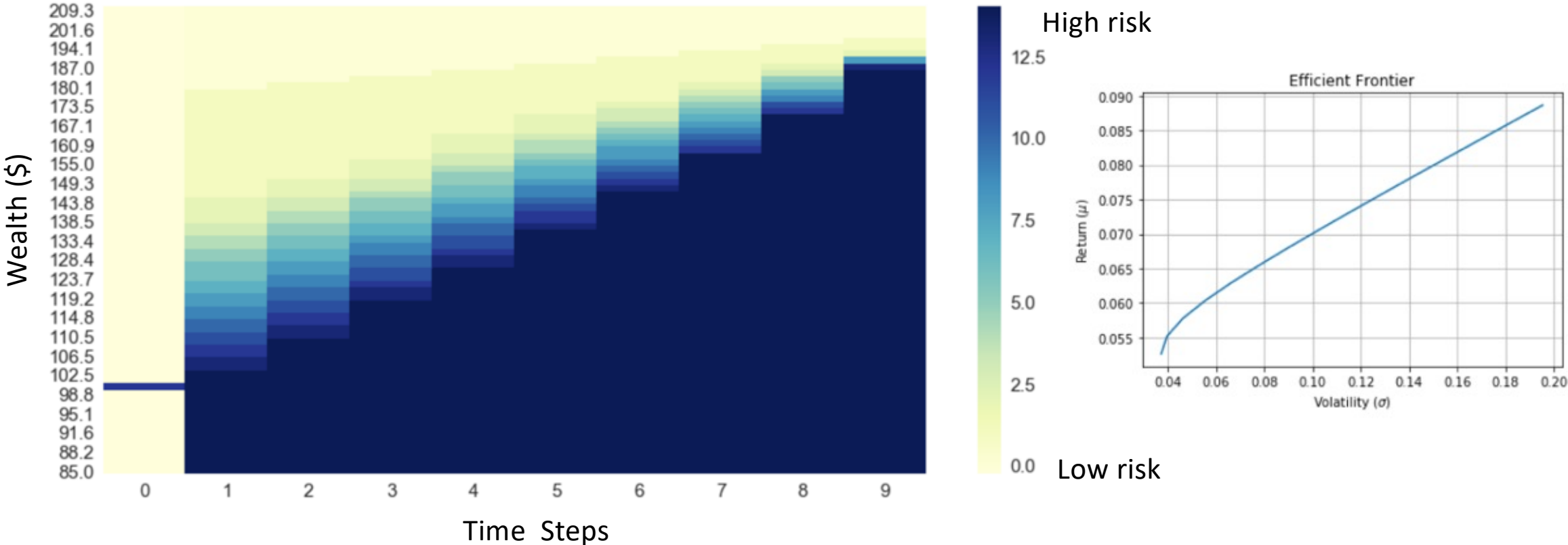


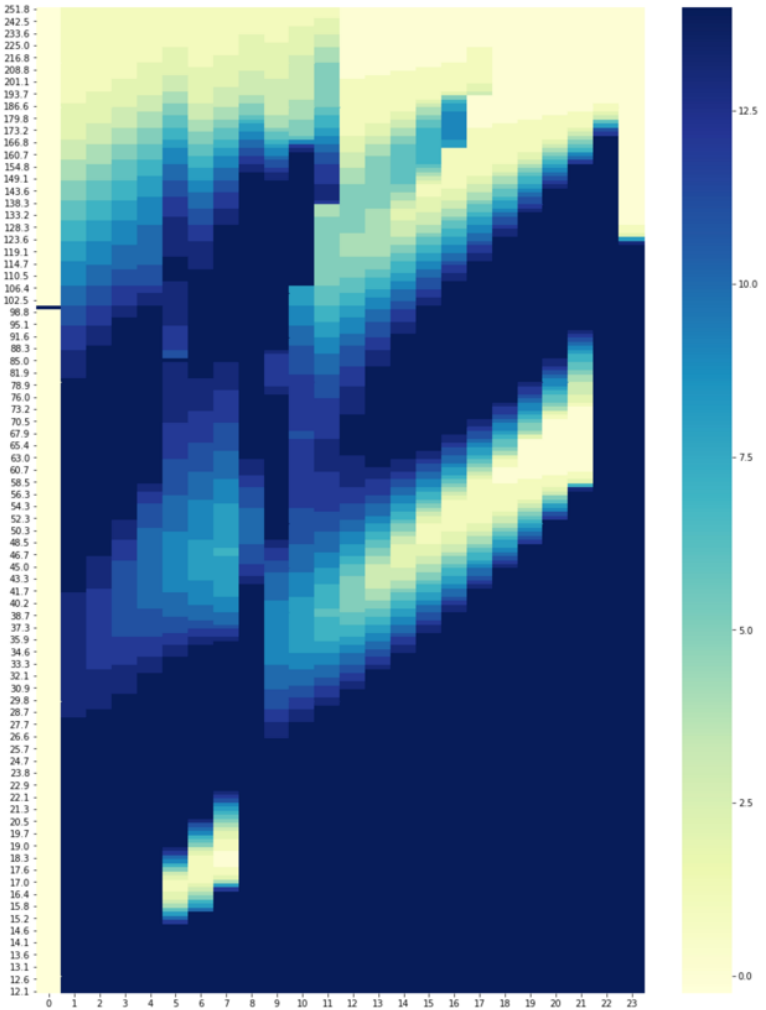**Optimal dynamic portfolio strategy** – grid corresponding to each wealth node and time

Wealth Goal: G = $200 after 10 periods

# Dynamic Portfolio Optimization – Example



Optimal probability (of reaching the goal), at each wealth node and time

Wealth Goal: G = $200 after 10 periods

# Dynamic Portfolio Optimization – Example



Example: Grid of optimal portfolios for multiple goals at different times

- Multi-criteria optimization using a utility function (weighting function for multiple goals)

# Modelling Dynamic GBWM

## The dynamic setting further allows to make the problem more realistic

- Handle multiple (competing) goals at different points in in time: e.g. buying a cottage in 2 years, vs. retirement vs. leaving inheritance

  - Handling different priorities and level of importance (via utility function)

- Goals at different level of the family hierarchy and multiple ways of funding

- Uncertain cashflows (inflows and outflows)

- Realistic financial details: e.g. tax assumptions

- Realistic economic model and stress scenarios…
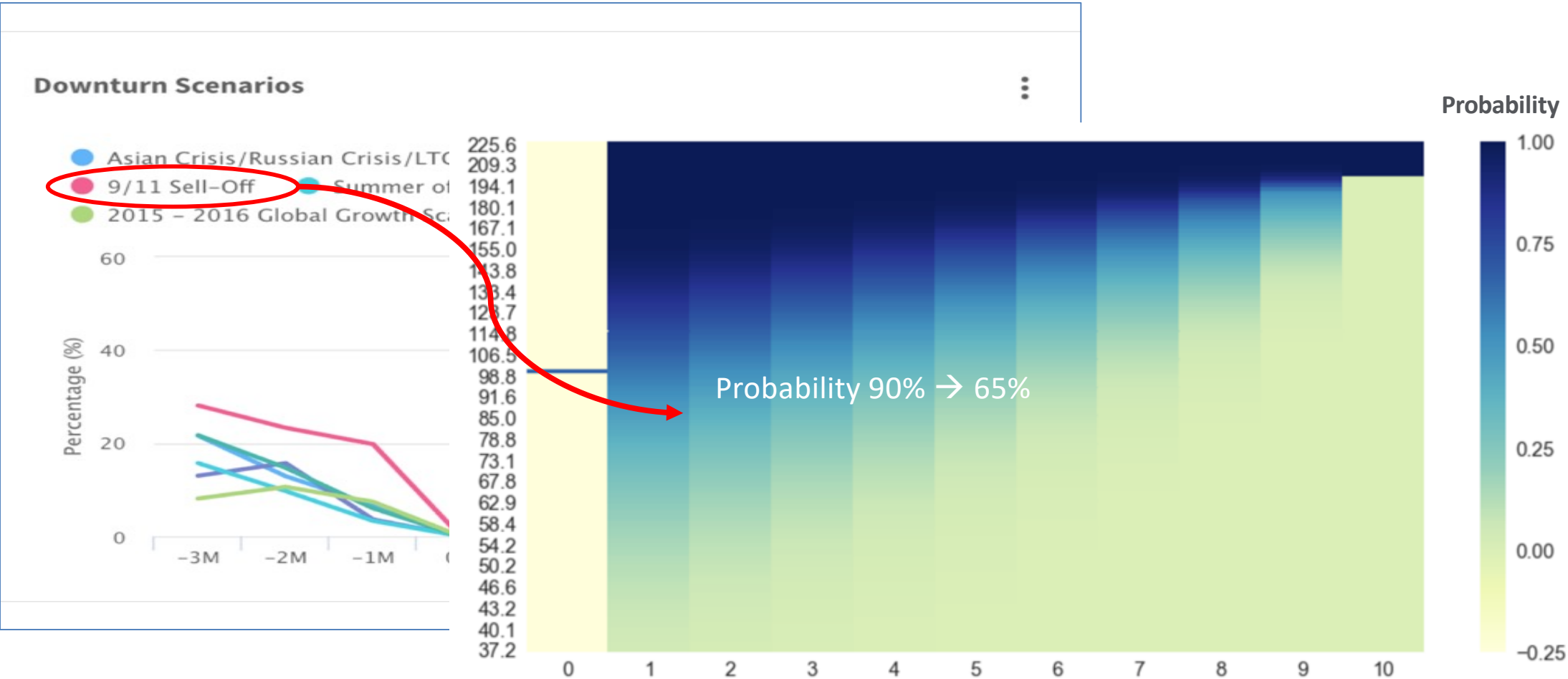
## The optimization setting also allows us solve for

  - Sensitivities, what-if analyses, trade-offs

  - Inverse problem: Find most likely scenario(s) or actions that may affect our goals – severity, timing…

# Overlaying Historical Scenarios
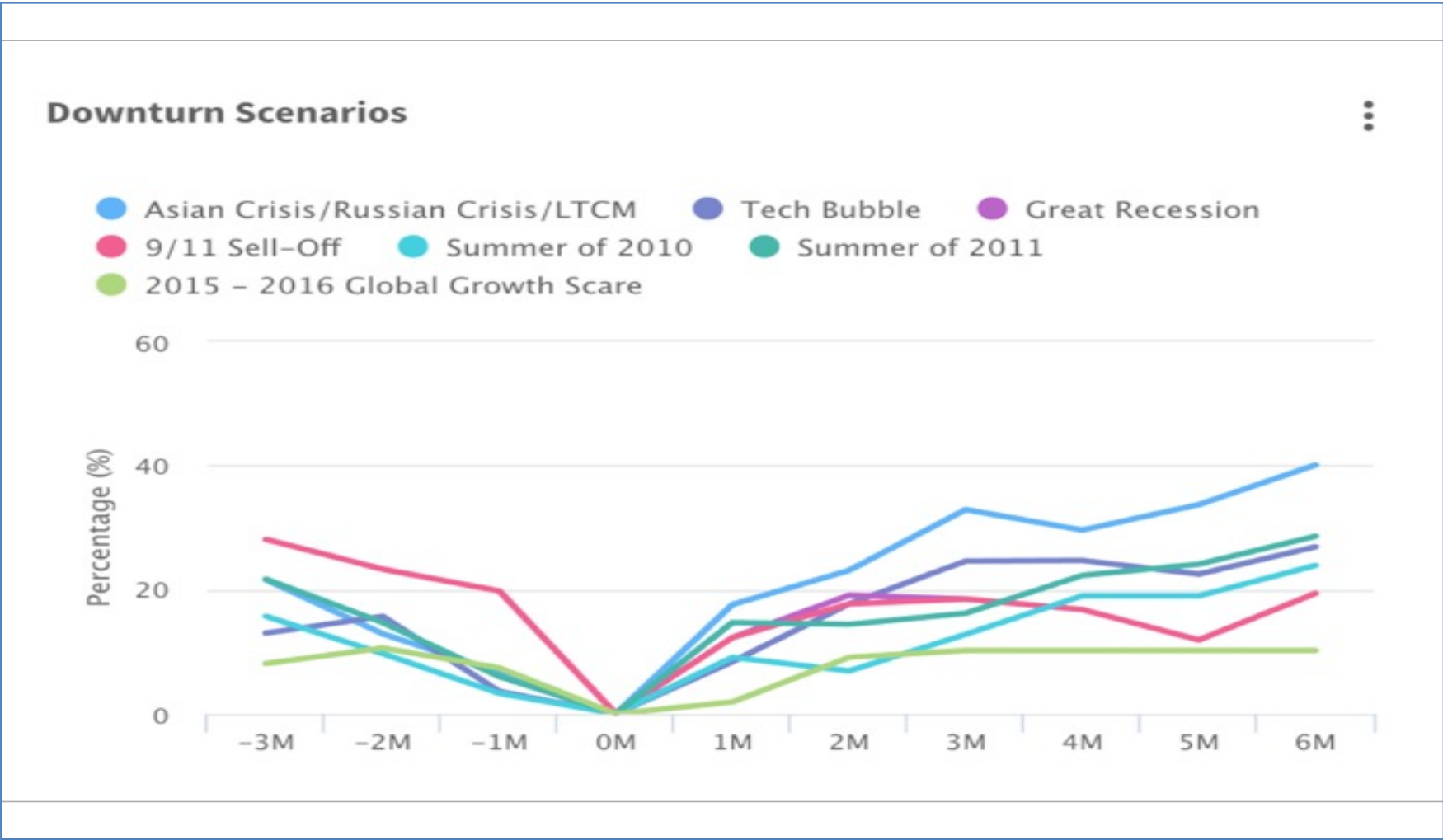
# Example: Overlaying Historical Scenarios & Drawdowns

# Dynamic Portfolio Optimization for GBWM

## What's the big deal?

- Most practitioners solve the planning problem over ONE SCENARIO… or 3 scenarios ☺

  - Good as a simple Base to understand the problem, but not realistic and does not incorporate risk!

  - Perform perhaps some stress testing

- Some perform a simplistic MC simulation with limited (simplified) asset classes and may test static portfolios or some simple strategies

- MPT-based single-step portfolio strategies that are rebalanced periodically

- Some attempts at dynamic optimization with direct asset allocation – lead to only simplistic goals, simplistic portfolios (small number of theoretical asset classes) which are difficult to implement and computationally intensive

ML tools such as Reinforcement Learning and NN are particularly well-suited for this problem and have now also opened the possibilities – computationally intensive and complex to implement

# In Practice… Financial Risk for Humans

Interactive engagement and coaching – multiple goals & questions the client/investor relates to

- How did the likelihood of achieving the goal changed with a recent drawdown?

- What's the max drawdown I can take? When do I need to worry?

- If I can't meet goal precisely, how far are we? What are my trade-offs between multiple goals?

- How else can I fund the plan?

- When can I de-risk portfolio? How much can I take out and not affect goal?

**Big Data, analytics, AI**

**and other digital technologies**

**will not eliminate**

**the need for the human touch….**