

# Catch-up Scheduling for Childhood Vaccination

Dr. Hannah K. Smalley, Sheila D. Isbell, Dr. Pinar Keskinocak, Dr. Faramroze Engineer, Dr. Larry K. Pickering (Emory University School of Medicine)



Acknowledgements (alphabetical order): Josh Cothran, Cathy Hogan, Arya Irani, Moon Kim, Shilpa Kottakapu

## PROJECT SUMMARY

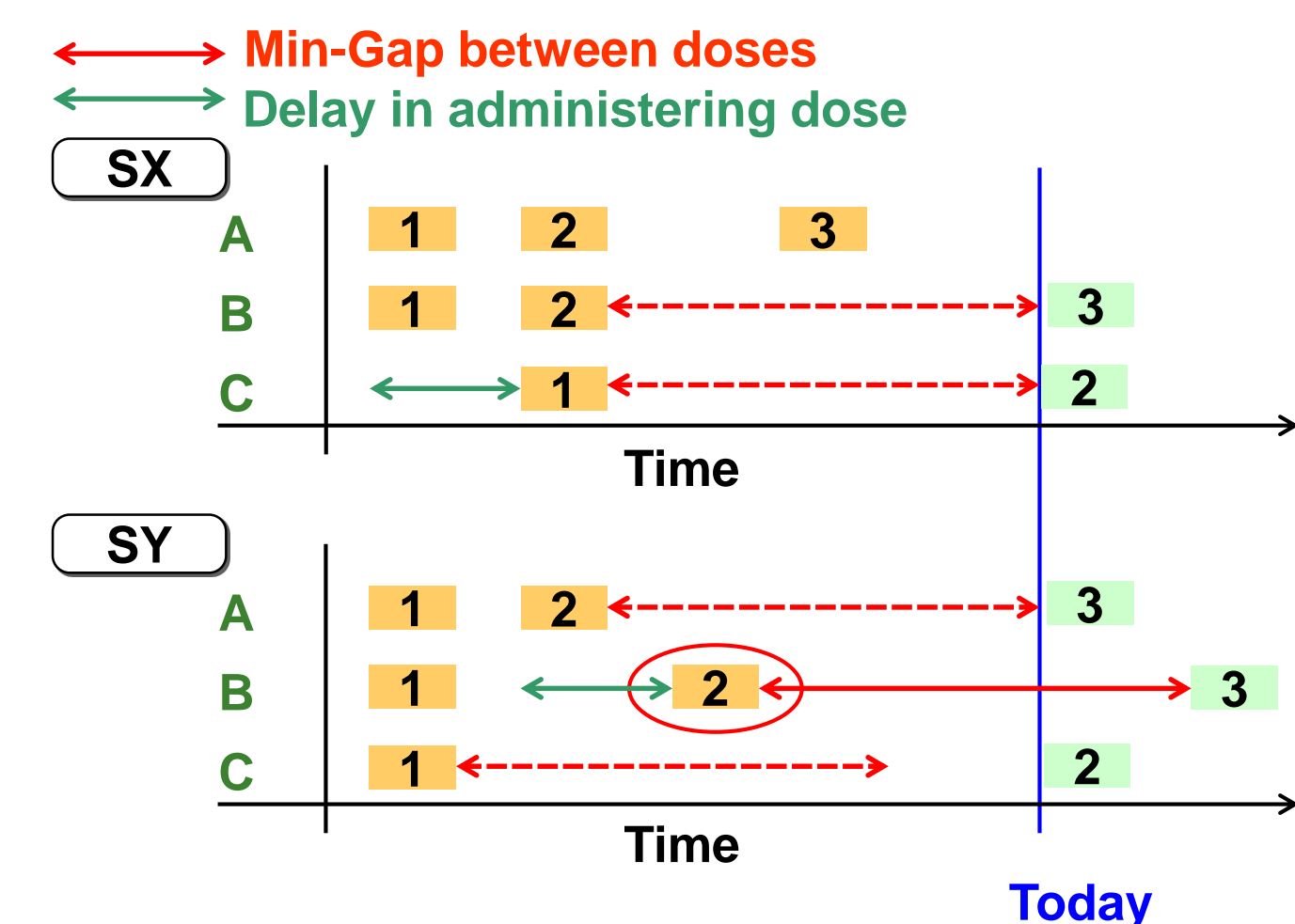
- Optimization based **decision support tool** to help caregivers and providers construct **catch-up immunization schedules**
- Ensure timely vaccination against vaccine preventable diseases as recommended by the Advisory Committee on Immunization Practices (ACIP)

## OBJECTIVES

- Timely vaccination rates
- Eliminate human error
- Expedite schedule generation
- Awareness and parental participation
- Public access to vital information
- Alleviate missed opportunities

## SCHEDULING

Given past vaccination history for a child, each remaining dose that can be **feasibly** administered and is **not contraindicated** must be scheduled:



### Dominance criteria

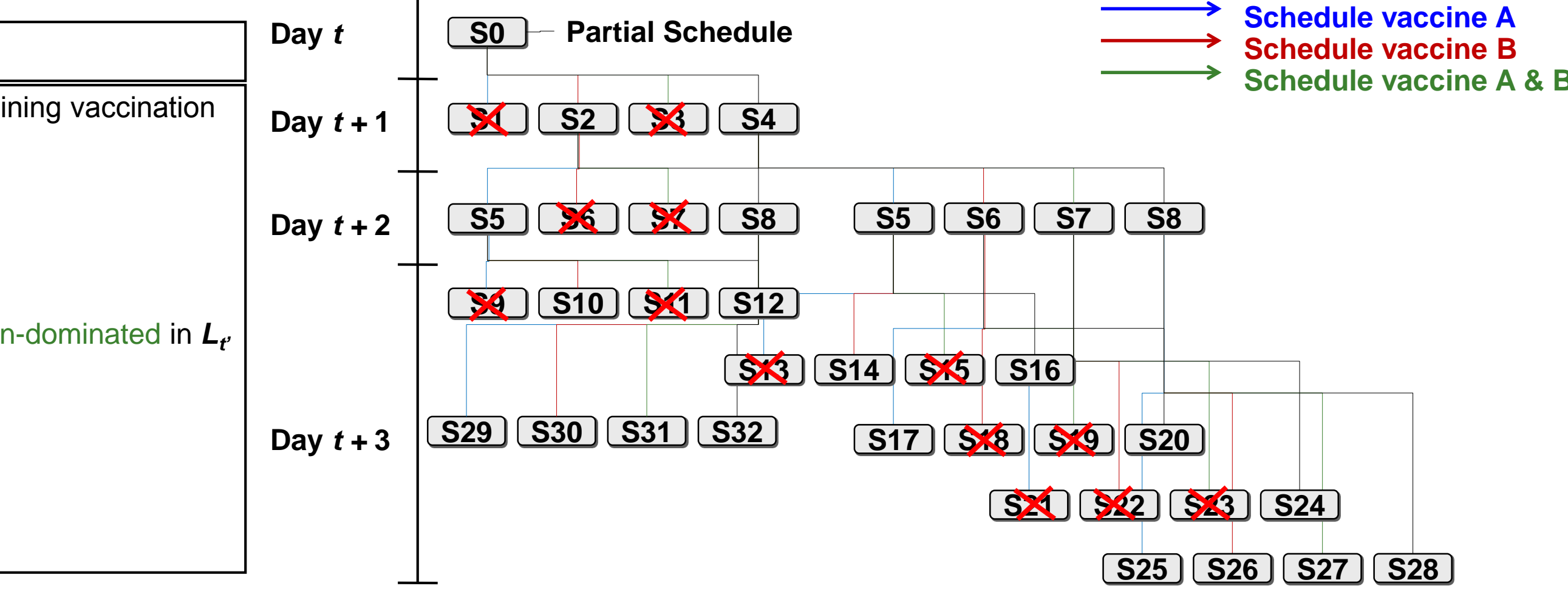
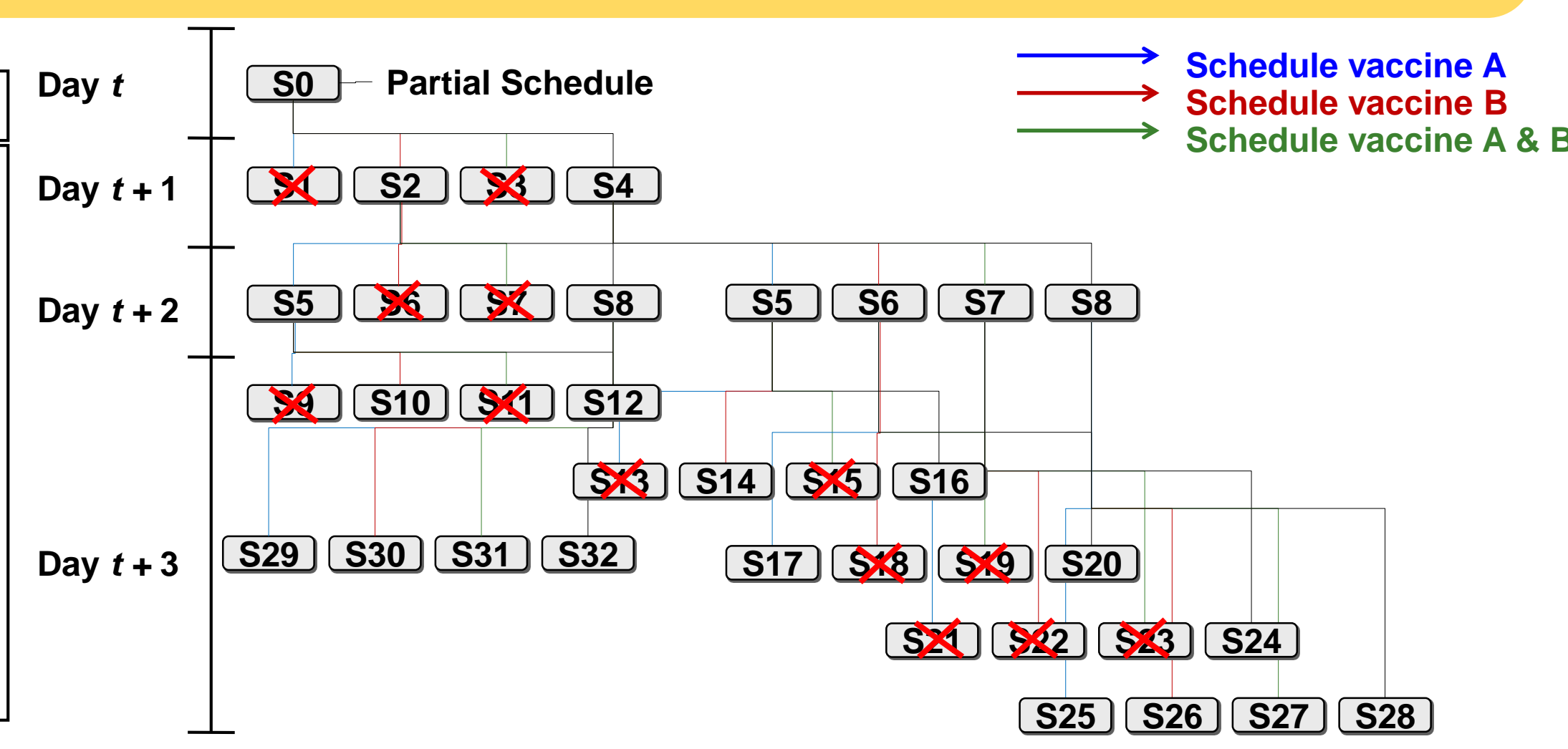
- Schedule **SX** dominates **SY** if:
- The **number** of doses administered in **SX** is no less than **SY** for each vaccine,
  - The **timing** of each **critical** dose administered in **SY** is no earlier than in **SX**, and
  - The total **delay** in administering doses in common is less in **SX**.

### Proposition

If **SX** dominates **SY** then any completion of **SY** cannot be better than the best completion of **SX** and thus, **SY** is unwarranted.

**Nomenclature:**  
**V** – Set of all vaccines  
**τ** – Planning horizon  
**M** – Max simultaneous admin  
**S** – Partial schedule  
**[S, V', t]** – Extension of schedule **S** obtained by scheduling all vaccines in **V'** ⊆ **V** on day **t**

**The DP Algorithm:**  
**Initialize:**  $S_0 \leftarrow$  initial schedule containing vaccination history up-to day  $t$ .  
**Main Loop:**  
 for all  $t' = t+1, \dots, |\tau|$   
 for all  $S \in L_{t'-1}$   
 for all  $V' \subseteq V$  s.t.  $|V'| \leq M$   
 if  $[S, V', t']$  feasible and non-dominated in  $L_{t'}$   
 insert  $[S, V', t']$  in  $L_{t'}$   
 end if  
 end for  
 end for  
 end for



## VACSCHEDULER.ORG

- Input birthdate and vaccination history
- Generates full recommended vaccination schedule

### Your personalized vaccination schedule:

Print Save Vaccination History Show Footnotes Edit History Start Over

Schedule Created On: 11/05/2015  
 Birthdate: 03/24/2015  
 Current Age: 7 months, 1 week, 5 days

Age	0-4 weeks	1-2 months	3-5 months	6-11 months	12-14 months	15-17 months	18-23 months	4-6 years	6+ years	Tally
Recommended Date	2015 03/24	2015 05/25	2015 07/27	2015 09/24	2015 11/05	2016 03/24	2016 06/24	2016 09/24	2017 02/24	2019 03/24
Hepatitis B (HepB)	AD	AD		OD						3/3
Rotavirus (RV)	AD	AD		CD						3/3
Diphtheria, Tetanus, Pertussis (DTaP)	AD	AD		CD	OD				OD	5/5
Haemophilus influenzae type b (Hib)	AD	AD		CD	OD					4/4
Pneumococcal (PCV)	AD	AD		CD	OD					4/4
Polio (IPV)	AD	AD		OD					OD	4/5
Measles, Mumps, Rubella (MMR)					OD				OD	2/2
Varicella (Chickenpox) (Var)					OD				OD	2/2
Hepatitis A (HepA)					OD			OD		2/2
Meningococcal (MCV)										
Influenza (Flu)										

Legend: AD Administered Dose ID Invalid Dose CD Catch-up Dose OD On-time Dose PD Preemptive Dose

## CURRENT SITE FEATURES

- Print schedule
- Save, upload, update vaccination history
- Display feasibility warnings
- Accelerated schedule option
- Links to CDC vaccine information sheets
- Footnotes for vaccine special cases
- Sign up for email updates
- Send feedback

## SCHEDULER USAGE

- 96,000+ site visits
- 3500+ accessed the site via iPad, 3300+ via iPhone
- Over 50% of visitors self-identify as healthcare providers

## FUTURE WORK

Online adolescent and adult immunization schedulers

## PUBLICATIONS

- Lasry, A., M. Washington, H.K. Smalley, F. Engineer, P. Keskinocak, and L.K. Pickering. "Public Health Modeling at the Centers for Disease Control and Prevention". *Operations Research and Healthcare Policy*. 2013.
- Smalley, H.K., F. Engineer, P. Keskinocak, and L.K. Pickering. "Universal Tool for Vaccine Scheduling – Applications for Children and Adults". *Interfaces*. 2011.
- Engineer, F.G., P. Keskinocak, and L.K. Pickering. "Catch-up Scheduling for Childhood Vaccination". *Operations Research*. 57 (2009).